An Inquiry into the Work and Progress of Interdisciplinary, University-Based Research Teams

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Dedication

This dissertation is dedicated in loving memory of my parents,

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Abstract

This dissertation employed a multiple-case research design to explore four interdisciplinary, university-based research teams and the factors that influence their work and progress. Analysis of the collected data, corroborated with the reviewed literature, resulted in the formulation of the mid-range theory on interdisciplinary, university-based research teams. The proposed mid-range theory entails three theses and the model of key factors influencing the work and progress of these teams. To further confirm (or disconfirm) the proposed theses, a number of propositions are presented. The dissertation research concludes with practical recommendations for researchers, HRD professionals, and university administrators.

Keywords: interdisciplinary research, research team, team science, case study

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Chapter 1: Introduction

Background to the Problem

There is an increasing realization that the traditional patterns of knowledge production have been changing rapidly (Nowotny, Scott, & Gibbons, 2001). According to Gibbons et al. (1994), we are entering "mode 2 of knowledge production," under which research is increasingly becoming collaborative, inventive, context sensitive, and problem solving oriented. The conventional mode of advancing science (aka "basic research"), while still most prestigious, is challenged by an increasing understanding within the scientific community that "applied research" – the application of science to pressing problems faced by society and individuals – is critical. The complexity of the problems (e.g., social, ecological, and health-related) requires collective efforts and expertise that extend beyond the boundaries of a single discipline and the capabilities of a single researcher or laboratory. Interdisciplinary, team-based research is becoming a dominant form of inquiry (Wuchty, Jones, & Uzzi, 2007).

This shift in the knowledge-production activity poses significant challenges for research-oriented organizations that are under pressure to adapt to the new environment. Some of the challenges relate to the structure of contemporary research universities (with their discipline-bound departments); others reside in the existing tacit norms hampering the interdisciplinary interaction (e.g., publishing interdisciplinary work in traditional, highly ranked journals may be challenging). Researchers who come from different epistemologies and fields often lack a common language (and perspective on the subject of investigation) that also complicates the processes of integration and combination of concepts, methods, and theories across fields.

Under the pressing challenges, many research institutions in higher education, including the University of Minnesota (U of MN), are seeking innovative strategies to broaden and deepen integrative research opportunities *across* and *beyond* their organizations. One of the examples of such strategic initiatives were the five-campus *Grand Challenges* research forums at the University held in October 2015 that aimed to "foster connections among distinct but potentially related disciplinary perspectives" (U of MN, 2016). While interdisciplinary research is gaining popularity, how to enhance the capacity of research institutions and disciplines to help scientists cooperate under conditions that are likely to produce conflict as well as innovation remains poorly understood.

Given the institutional and organizational demands, more and more scholarly attention is being given to *team science* – "scientific collaboration, i.e., research conducted by more than one individual in an interdependent fashion, including research conducted by small teams and larger groups" (Cooke & Hilton, 2015, p. 22). Specifically, several special journal issues on team science have been published recently (e.g., Stokols, Hall, Taylor, & Moser, 2008), and a number of reports have also explored the state of team science in different countries (e.g., Academy of Medical Sciences, 2016; Bammer, 2012).

While research about teamwork is extensive, prior research mainly focused on teamwork in industry and business. This research continues to serve as an important point of reference for scholars who study *team science*. Similar to the management and organizational studies, studies of team research underscore the importance of institutional support, leadership, and strong communication skills for effective team science (Bennett,

Gadlin, & Levine-Finley, 2010). At the same time, not all research findings from industry and business can be directly applied to *team science*. For instance, most research on teams comes from studies on teams that functioned within a short time-frame and typically had clear deadlines; in contrast, the life-span of interdisciplinary research teams may take several years. In addition, while interdisciplinary research may by initiated by the administration or the government(s) in the form of large-scale, "challenge-led" research projects, it is more typically researchers themselves who initiate interdisciplinary research, which makes it a "bottom-up" rather than "top-down" initiative.

Problem Statement

Despite the growing scholarly interest towards team science, and the extant research on teamwork in other fields, scholars underscore that the literature on team science has paid a great deal of attention to "the definitional scramble over existing approaches" and also examined barriers towards cross-disciplinary collaboration, including the tensions between interdisciplinary and disciplinary communities (Siedlok & Hibbert, 2014, p. X). At the same time, there is a recognized need for the exploration of resources and infrastructure within and across institutions to promote team science as well as processes and methods that would encourage and support inter- and transdisciplinary research teams (Cooke & Hall, 2015; Falk-Krzesinski et al., 2011).

My review of the literature also suggests that while team science scholars have predominantly focused on large-scale team research projects (e.g., Stokols et al., 2010), there is scant empirical research that would have addressed the work of interdisciplinary research teams of smaller size in the academic settings. As Cummings and Kiesler (2011)

observed, “little is known about how (and if) universities create values, procedures, and structures wherein interdisciplinary science is central” (p. 3). The authors called for the utilization of organizational theory to address the new organizational forms and ways of working that comes with the change in knowledge production.

Lastly, various scholars also underscored the need for a multi-level systems perspective to advance the science of team science (Börner et al., 2010). However, the most of the proposed frameworks underscoring a multi-level approach toward team science are the result of scholars’ theorizing based on their professional experiences with team science or literature reviews drawn from a number of fields (e.g., Börner et al., 2010; Stokols, Misra, Moser, et al., 2008).

Research Question

This dissertation addresses the above-discussed gaps in research and practice in the context of team science and, specifically, focuses on the exploration of interdisciplinary research teams in the context of public research universities. The guiding research question that the study aimed to investigate was as follows:

What factors influence the work and progress of interdisciplinary research teams in the context of a public research university?

In the process of conducting the study, which employed a multiple-case research design, I gained deep insights into interdisciplinary, university-based research teams as a distinct form of human systems situated in a particular context. My analysis of the examined four teams, corroborated with the reviewed literature, resulted in the formulation of the mid-range theory on interdisciplinary, university-based research teams, which entails three theses and the model of key factors influencing the work and

progress of these teams. In addition, a number of propositions, presented in Chapter 5, set directions for future research that will allow to further confirm (or disconfirm) the proposed mid-range theory.

In the following sections of the chapter, I discuss the significance of the study and philosophical perspectives underlying the study, as well as elaborate on my personal interest, previous research, and experiences that informed the inquiry.

Significance of the Study

The study advances the practice of team science, and, in particular, of interdisciplinary research teams functioning in the context of public research universities. The study also promotes the theoretical understanding of interdisciplinary, university-based research teams as a distinct form of human systems situated in particular contexts, and also sheds light into the factors that influence the work and progress of these teams.

As the traditional research university model, built around the discipline-based scholar, has been undergoing transformations in recent years (Schuster & Finkelstein, 2006), the study contributes to the discourse on the changing nature of higher education and offers practical recommendations for university researchers and administrators on the actions that may enhance interdisciplinary research in their institutions. This research may be also of interest to other relevant stakeholders (e.g., funding agencies, research institutions), as the study findings provide insights on the various organizational conditions that can influence the work and progress of interdisciplinary research teams.

The study findings may be also of interest to OD/HRD practitioners working in research-oriented institutions on creating appropriate "systemic implementation" (Rhoten, 2004) that could lead to a higher number of (and also more effective)

interdisciplinary research initiatives at the organizations. As noted by Cho, Cho, and McLean (2009), despite the growing interest in knowledge management (KM) in the field of HRD, "existing literature lacks a thorough explanation of how tools, processes, and theories of KM can be harnessed, advocated, and championed by HRD professionals" (p. 264). Specifically, there is still a lack of understanding on what triggers *collaborative* knowledge creation (emphasis is intentional), how it happens, and, how HRD professionals can assist organizations in facilitating it (Chatenier, Verstegen, Biemans, Mulder, & Omta, 2009).

Lastly, the study findings contribute to the growing literature on team science and promise to further advance our understanding on how interdisciplinary research teams function and what factors enable or hamper their work and progress. As noted by Cooke and Hilton (2015), the literature on team science often lacks empirical evidence. As this study employed a qualitative approach, the study findings provide a contextually rich perspective on the work and progress of interdisciplinary research teams in the context of a public research university. In addition, as noted above, the study provides a number of propositions that set directions for future empirical research.

Key Definitions Employed in the Study

This sub-section provides an overview of the following terms employed in the study: interdisciplinary research, research team, work, and progress.

Interdisciplinary Research. The term *interdisciplinary research* is used as a general term to describe research activities that span disciplinary boundaries (e.g., Frodeman, Klein, & Mitcham, 2010). The definition by the National Academy of Sciences (2004) is among the most widely employed:

> [Interdisciplinary research is] a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice. (p. 26)

There is, however, no consistency among scholars how to frame different *modes of research* when several individuals from different disciplines and areas of practice collaborate with each other; the topic remains a contested area (Stokols, Misra, Moser, Hall, & Taylor, 2008). Most recently, the following three modes of cross-disciplinary research – *multidisciplinary – interdisciplinary – transdisciplinary* – have been proposed to be viewed on the continuum, "ranging from low to higher levels of integration and potential for innovation" (Stokols, Hall, & Vogel, 2013, p. 5). In this case, scholars place *multidisciplinary* and *transdisciplinary* forms on the opposite sides of continuum, while the *interdisciplinary* form is conceived somewhere at the midpoint. Each of the modes possess its defining characteristics, as can be seen in Table 1 below.

Insert Table 1 about here

In this study, I sought to explore those research teams that had a high potential for innovation and, based on their team composition and research activities, were also transcending some pre-existing disciplinary boundaries and/or were promising to do it during the time of my study. As research in multidisciplinary, interdisciplinary and transdisciplinary environments is often seen as complementary (e.g., Frodeman, Klein, &

Mitcham, 2010; Lawrence, 2004), and different levels of integration can be apparent at various stages of research (Cooke & Hilton, 2015), the study employed "interdisciplinary research" as a general term that incorporated both interdisciplinary and transdisciplinary forms of research undertaking.

Research team. In the context of this inquiry, I employed Kozlowski and Ilgen's (2006) conceptualization of team that is characterized by the following attributes:

> (a) two or more individuals who (b) socially interact; (c) possess one or more common goals; (d) are brought together to perform organizationally relevant tasks; (e) exhibit interdependencies with respect to workflow, goals, and outcomes; (f) have different roles and responsibilities; and (g) are together embedded in an encompassing organizational system, with boundaries and linkages to the broader system context and task environment (p. 79).

Similar to Kozlowski and Ilgen's (2006), who noted that the words "team" and "group" often used interchangeably these days, in my review of the literature, I came across a number of studies that employed the term "research groups." At the same time, as I was looking for the established (formed) collectives conducting research, i.e., collectives who had defined research objectives, had clear understanding of who was on the team, and who could be characterized by a medium-to-high level of interdependence among team members, I decided to use the term "research team." The selection of the term was also in line with the emerging "science of team science" stream of research (Cooke & Hilton, 2015).

Work and Progress. The selection of terms "work" and "progress" was also deliberate, and made with consideration of modern perspectives on work teams, which

view them as "complex dynamic systems that exist in a context, develop as members interact over time, and evolve and adapt as situational demands unfold" (Kozlowski & Ilgen, 2006, p. 78). In addition, these broad definitions reflect the inductive nature of the study, as the selected method of inquiry suggests refraining from clearly defined constructs in the process the data collection.

The American Heritage Dictionary of the English Language defines *work* as "physical or mental effort or activity directed toward the production or accomplishment of something" (2016). In turn, *progress* is defined as (a) "forward or onward movement, as toward a destination" and (b) "development, advancement, or improvement, as toward a goal" (2016). In this study, I used these broad concepts as opposed to some pre-defined constructs of what constitutes interdisciplinary research teams' productivity and/or performance. The selection of the definitions was somewhat in line with those modern perspectives on work teams that view "team performance as an active, dynamic, ongoing process rather than a retrospective evaluation" (Kozlowski & Ilgen, 2006, p. 95). As the authors submit, "what teams *do* – their actions to strive toward goals, resolve task demands, coordinate effort, and adapt to the unexpected – constitute team performance" (p. 95).

Philosophical Perspectives Underlying the Study and Assumptions

The study has been carried out within a critical realism perspective. In this case, I assumed that interdisciplinary research was "real" and that it was likely to be different, at least in some ways, from other forms of research undertaking (e.g., when all researchers are from the same discipline). I also assumed that interdisciplinary research occurs in teams and that the teams' work and progress might be different under the presence or

absence of particular factors. At the same time, I did not assume that there were fixed categories that were clear and precise, but rather that both interdisciplinary and team research are, to a great extent, social constructs that may be interpreted differently depending on the researchers, particular problems being addressed, organizational/institutional settings, etc. Finally, although I gained some personal experience with interdisciplinary research and did an exhaustive literature review on the topic, I anticipated that relatively little was known about how interdisciplinary, university-based research teams interact with their external environments, so it was important to approach the problem with the eye of a naïve observer.

Personal Interest, Previous Research, and Experiences

As a scholar-in-training, I have been quite curious to find out how, despite various challenges, backgrounds, and traditions, scholars from different fields find a common language and work as a team to address complex problems and advance science. My scholarly interest in the subject matter was strengthened by a pilot study that took place in Spring 2015. The objective of the study was to gain some preliminary knowledge on how interdisciplinary research groups emerge and function in the context of a public research university. To collect data, I conducted in-depth interviews with interdisciplinary scholars affiliated with the University. During the interviews, several researchers discussed that some research projects that they participated in were less satisfying than they could have been. Some scholars also noted some enablers that facilitated their work (e.g., getting a small grant via the Institute of Advanced Studies). Another researcher discussed how the conceptual framework conceived in their previous

project became important for the group to receive a grant to undertake another, more advanced, research project.

In October 2015, I also worked as a recorder at the four *Grand Challenges* research forums (U of MN) that aimed to "foster connections among distinct but potentially related disciplinary perspectives" (U of MN, 2016). This experience provided important insights on interdisciplinary research activities at the organization level, as the forums were well-attended by a wide range of the personnel, including faculty, research associates, administrators, graduate students and staff (e.g., librarians). What I observed in the forums supported the ideas that I was reading about in the literature – interdisciplinary inquiry is increasingly becoming an important component of research universities' strategic positioning. Understanding how these institutions can create conducive conditions for developing and enhancing interdisciplinary research becomes crucial to their survival and prosperity.

In sum, the exploratory study and my related experiences (e.g., my participation at the Grand Challenges research forums) provided me with valuable insights and helped grounding my research question in the real phenomenon that warrants further investigation. As I will note in Chapter 3, the researchers and administrators I got acquainted with also served as an important point of reference to the identification and selection interdisciplinary research teams for the study.

Chapter 2: Literature Review

In Chapter 1, I presented the background to problem, research problem, the research question that guided the study, and its significance. I also elaborated on the key definitions the study employed, my philosophical perspectives and assumptions

underlying the study, and also discussed my personal interest, previous research, and experiences that informed the study. In this chapter, I review key studies and frameworks that informed my investigation. Specifically, the purpose of this chapter is to review the literature that informed the inquiry on what is known on the subject matter – interdisciplinary research teams as well as factors influencing their work and progress – and also to identify those areas of research and practice that still lack understanding.

First, I will provide an overview the literature on team science, paying attention to the literature that reviews collaboration and teamwork in research. What follows is a discussion of the works that focused on factors influencing the work of research teams. The chapter concludes with the summary how the inquiry addresses the identified gaps in the literature and contributes to the existing body of knowledge.

The Science of Team Science

Over the recent decades, there has been an enormous increase in the demand for cross-disciplinary collaboration due to the various challenging societal and scientific problems that the mankind is facing today (Cooke & Hilton, 2015). The complexity of the problems (including ecological, economic, and health-related problems) requires a broad perspective and collective efforts that extend the boundaries of a single discipline and capabilities of a single researcher. As a result, team-oriented research, with researchers and experts representing more than one discipline or area of practice, is becoming a dominant form of inquiry (National Academy of Sciences, 2004; Porter & Rafols, 2009; Wuchty, Jones, & Uzzi, 2007).

Various empirical studies suggest that we are witnessing an unprecedented growth of team-based research (e.g., Wuchty, Jones, & Uzzi, 2007; Porter & Rafols, 2009).

Drawing from a study of 19.9 million research articles (examined over five decades), Wuchty, Jones and Uzzi (2007) concluded that research is progressively undertaken in teams across nearly all fields. In particular, the authors observed that in sciences, and, specifically, in such fields as medicine, biology, and physics, a mean team size doubled over the period of 1950 to 2000. Even in such fields as arts and humanities, where single authors traditionally produced the bulk of research, there was also a positive trend toward teamwork. Similarly, Porter and Rafols (2009) reported an approximately 75 % increase in the number of co-authors per article between 1975 and 2005, and about 50% increase in the number of cited disciplines per article for the same period.

The increase of interdisciplinary, team-based research has attracted attention of various scholars and resulted in the emergence of stream of research called "science of team science." As Börner et al. (2010) discussed:

> [Science of team science] is an emerging area of research centered on examination of the processes by which scientific teams organize, communicate, and conduct research (…). The field is concerned with understanding and managing circumstances that facilitate or hinder a range of collaborative research efforts—from determining the effectiveness of large-scale collaborative research, training, and translational initiatives to understanding how teams connect and collaborate to achieve scientific breakthroughs that would not be attainable by either individual or simply additive efforts. (p. 2)

Over the last decade, team science scholars have examined various aspects of scientific collaboration conducted both in research teams and in larger groups (Cooke & Hilton, 2015). In particular, several reports have explored the state of team science in

different countries (e.g., Academy of Medical Sciences, 2016; Bammer, 2013) and a number of special journal issues on the topic have also been published (e.g., Stokols, Hall, Taylor, & Moser, 2008). Across the many studies, scholars recognize that, while interdisciplinary research suggests a higher potential for innovation, the process of integration and combination of concepts, methods, and expertise across various disciplines requires additional efforts on the side of both researchers and institutions, and may encounter various challenges (e.g., Tress, Tress, & Fry, 2007).

Modes of research in cross-disciplinary collaboration. As noted in the Introduction chapter (see the definition of interdisciplinary research by the National Academy of Sciences, 2004), integration of knowledge and expertise from two or more disciplines or bodies of specialized knowledge is one of defining characteristics of cross-disciplinary research collaboration. Scholars, however, have not yet reached an agreement on how to frame different *modes of research* when several individuals from different disciplines and areas of practice collaborate with each other; the discussion is ongoing (Hall et al., 2008; Stokols, Hall, & Vogel, 2013). The following four types of integration are frequently mentioned in the literature (e.g., Wagner et al., 2011):

(a) *unidisciplinary* – all researchers are from the same discipline, i.e., no integration;

(b) *multidisciplinary* – engagement of scholars from several disciplines; contributions are made in a sequential and/or additive way;

(c) *interdisciplinary* – also several disciplines, but contributions are made via the integration of perspectives, concepts, and approaches from different disciplines; and

(d) *transdisciplinary* – not only integration of disciplines, but also creation of fundamentally new frameworks and approaches, "that synthesize diverse approaches but also *transcend* pre-existing disciplinary boundaries" (Stokols, Hall, & Vogel, 2013, p. 5).

At the same time, some scholars observe that different levels of integration can be evident at different stages of research undertaking (Cooke & Hilton, 2015). In addition, what is recognized as inter- (or trans) disciplinary research today may become disciplinary in the nearest future (National Academy of Sciences, 2014).

In sum, the discussion on framing different modes of research continues. Most recently, some scholars suggested that the distinction between transdisciplinary and interdisciplinary research should be based not on the degree of synergy or integration but rather on the inclusion of contributors from outside academia (Stokols et al., 2010).

Similar yet Different: Interdisciplinary Research Teams

As the study's focus is on interdisciplinary research teams working in the context of public research university, what follows is the overview of some key differences between interdisciplinary research teams (including, but not limited to university-based research teams) and other teams functioning in different contexts, as noted in the literature. When discussing the differences, scholars often note several aspects on which interdisciplinary university-based research teams differ from other teams that are not engaged in research: (a) team composition in the academic settings and (b) maturation/development of inter- and (trans) disciplinary research teams.

Team composition in the academic settings. While the team composition of academic research teams may vary in terms of the number of researchers, there are several important aspects related to the teams' composition that make university-based

research teams different from other (commercial) research teams. First, academic research teams typically consist of a senior researcher (a research group leader / primary investigator) and a number of junior researchers (PhD students and/or post docs). The research of university-based teams is usually financed through various grants that the senior researchers apply for. The grant funding that research teams receive often pays for graduate students and post-doc scholars working in these teams. Members of the research teams are often expected to publish their work in academic journals. In turn, research teams in other (commercial) contexts differ from academic research teams in several ways. The former typically employ scientists who already graduated from research institutions. The work of (commercial) research teams is often directed towards the profitability of their companies. While members of commercial teams may not be expected to publish, they have their own pressures and expectations, typically set by senior executives.

The above-presented differences between the academic research context and other research contexts set certain expectations for both senior and junior researchers that may impact their behaviors. For instance, in a study that explored leader-member exchange and creative performance of research groups in academic and commercial settings, Olsson, Hemlin, and Pousette (2012) observed that, depending on the context, group leaders and group members behaved differently.

Maturation/development of science teams. While organizational research on team/group development has been extensive and offered several unified models (e.g., Tuckman, 1965; Gersick, 1988), recent studies on team science have also highlighted some peculiarities attributed to the maturation and development of science teams. Thus,

Hall et al. (2012) proposed a model of transdisciplinary team-based research that underscores four overlapping and recursive phases – development, conceptualization, implementation, and translation; suggesting that interdisciplinary research teams possess some unique features that make them distinct from the teams and groups that are not engaged in research.

During the *development* stage a group of potential collaborators convenes "to define the scientific or social problem space or interest" (p. 3). The process gets initiated by an individual or a small core group. During this phase, the group identifies a general area of interest and gets a more comprehensive understanding on the disciplines and perspectives necessary to address the problem area. At this stage, the nature of membership is fluid. New members may join the initiative to explore the research opportunity. Some members who initially contributed to the initiative may decide to withdraw. In the *conceptualization* phase, the group determines specific knowledge gaps in the problem area as well as identifies approaches to address them. During this phase, the group develops research questions and also determines a set of expertise necessary to undertake the project. During this phase a research team starts to coalesce.

During the *implementation* phase, the group launches, conducts, and refines the planned inquiry. This is the time when the group represents a "real" team (Hall et al., 2012). According to West and Lyubovnikova (2012), *real* teams are characterized by (a) high interdependence, (b) shared objectives among the team members, (c) high reflexivity (team members review their performance and make adaptations to their goals in the process), and (d) boundedness (team boundaries are not permeable, there is a clear understanding who is on the team). In turn, during the *translation* phase, the team works

on moving research findings "from one level of analysis to another" and also "across the discovery-development-delivery continuum" to provide solutions to real-world problems (Hall et. al., 2012). During this period, other "translational partners" can be involved in the project. These partners can be practitioners, community members, or policy-making professionals.

In sum, interdisciplinary research teams, and university-based research teams in particular, differ from various other types of teams that function in other professional contexts. Because of these differences teams may encounter different challenges in their work; hence, an in-depth inquiry into the work of the teams, with attention to the contextual factors that may influence their work, is promising to advance our understanding on how to facilitate the team's work. In the section below, I discuss the literature that examined various factors influencing research team's effectiveness and performance.

Literature on Factors Influencing Research Collaboration

Many studies have explored factors associated with the success or failure of interdisciplinary research collaboration. Although some have built on previous research in organizational studies, my review focuses on the team science literature as a basis for my data collection and analysis.

Findings of studies on research teams pointed to various factors influencing interdisciplinary research. The review of the literature also suggested several levels of analysis that scholars considered in their research. The following review is organized around the three levels (individual, group/team, and organization/institutional levels), pertinent to the study's focus at the time when the review was conducted.

Individual Level. Researchers' attitudes, values, motivations, and experiences were found to be crucial to success of interdisciplinary research initiatives. Thus, researchers who support culture of sharing, exhibit collaborative readiness (preparedness for uncertainties of interdisciplinary research activities), as well as have previous experience in working cross-disciplines were argued to advance the prospects of interdisciplinary research initiatives (Stokols, Misra, Moser, et al., 2008). In turn, in the study that examined two large-scale landscape analysis projects, Jakobsen, Hels, and McLaughlin's (2004) found that such personal characteristics as arrogance, a big ego, interest and participation in power-plays internal to the respective teams, stereotyping, caginess, and narrow-mindedness among researchers were seen as barriers to cooperation.

Motivation to become involved in interdisciplinary research was noted as an important factor influencing research collaboration (e.g., Rhoten, 2004; Siedlok & Hibbert, 2014). In particular, Rhoten (2004) underscored the role of intrinsic motivation; the author observed that, in contrast to the image of researchers as imprisoned by their disciplinary silos, many scientists in their study "were driven to the edges of their fields" (p. 8). In turn, Siedlok and Hibbert (2014) discussed that, in addition to striving for novelty, some researchers get involved with interdisciplinary research because of frustration of the limits of their own discipline. The authors also observed that such extrinsic motivational factors, such as career opportunities or opportunities to access funds, may be another driver for scientists to do interdisciplinary research.

Leadership skills of team leaders were also found to be another important success factor (Harvey, Pettigrew, & Ferlie, 2002). Harvey, Pettigrew, and Ferlie (2002)

discussed that the requirements for leadership skills are changing as leaders face more business-oriented and complex environments. The authors found that "enterprising leaders" who were able to provide network connectedness within the institution and beyond it (nationally/internationally), and were an important "success" factor of high-achieving medical and medical-related groups. In turn, Stokols, Misra, Moser, et al. (2008) theorized the importance of inclusive and empowering leadership for team leaders of research groups. According the authors, team leaders who exhibit such leadership behaviors are more likely to create trusting relationship and team cohesiveness in their research groups.

Recent quantitative studies that examined differences at the individual level suggest that there are no significant differences in such demographic characteristics as race, age, and ethnicity with regard to individuals who conduct interdisciplinary research and who do not (Butler, 2011). With regard to gender, while some studies found that there were no differences in terms of gender (e.g., Butler, 2011; Salazar, Lant, & Kane, 2011), recent studies suggest that context matters. Thus, van Rijnsoever and Hessels (2011) observed that female researchers appeared to engage more in interdisciplinary research activities (their study was limited to the Utrecht University). In addition, in the study that explored whether a team's gender composition predicts how well women's expertise is employed within the research team, Joshi (2014) found that, in disciplines with a greater female faculty representation, teams with a higher proportion of highly educated women were perceived as more productive (the study employed peer-evolutions of male and female team members).

Team/Group Level. This section outlines those team/group-level factors that have been connected to the success and failure of research collaboration in team science literature. First, it discusses those factors that represent *team composition and assembly*. Then, it reviews those studies that highlighted various team process factors and emergent stages evident during the development of research teams and which are also associated with team effectiveness in the literature.

Team composition and assembly.

Team/group size. Research groups may range from a small number of scientists working at the same site to dozens and more researchers working at various institutions. The increase in the size of research groups is often discussed as a double-edge sword effect. While a research group of a larger size is expected to have a greater scientific expertise in the group, a larger group also requires greater amount of time for communication and coordination of work among its members (Wuchty, Jones, & Uzzi, 2007). In a recent report, commissioned by the National Research Council, Cooke and Hilton (2015) defined team science conducted by two to ten individuals as *science teams*. In turn, team science conducted by ten or more individuals were referred to as *larger groups* in the report. As group size is often considered an important control variable in team research (Wheelan, 2009), I focused on teams with two to ten individuals (science teams), as opposed to examining groups of larger sizes.

Diversity in membership. The underlying assumption behind interdisciplinary research projects is the participation of individuals with diverse knowledge, skills, and perspectives that ultimately leads to accelerating important scientific discoveries (Fiore, 2008; National Academy of Sciences, 2004). In addition to various demographic

differences (e.g., age and gender), members of research groups may differ in their preferences toward (and expertise in) research methods/epistemologies, levels of analysis, as well as have different motivations (e.g., how to disseminate the findings of their research). While a high level of diversity, under the conditions when group members build on each other's expertise, is positively associated with research group creativity and effectiveness, it may also bring additional costs (Cooke & Hilton, 2015). Unless addressed timely and appropriately, these and other differences among researchers may negatively influence the research team's effectiveness (Bezrukova, 2013). For instance, Younglove-Webb, Thurow, Abdalla, and Gray (1999) observed that the insufficient disciplinary grounding between group members early in a research project caused some difficulties later in the group; when the group members attempted to converge on a unified conceptual framework.

Change in team membership. Due to the relatively long implementation of interdisciplinary research projects, turnover in research team composition is becoming a norm. While the change can be beneficial (e.g., new members may bring a different set of perspectives and connections to communities outside of the team), turnover in team composition is often associated with anxiety and uncertainty in research teams, which, in turn, negatively influences team dynamics and can affect the implementation of research project at different stages of its life-cycle (Younglove-Webb et al., 1999). For instance, Louis, Holdsworth, Anderson and Campbell (2008) discussed a case in which a change in team composition severely hampered the dissemination of project results (a publication that had already been accepted by a high-ranking journal). One individual, who was promised the first authorship early in the long-term project, left the lab for another job

two years before the project ended (an event that had not been foreseen when the project was launched). Who should be the first author on the publication became a matter of heated disputes between the individual and the group.

In the team science literature, scholars have also recognized some other factors related to the team assembly aspect; however, these factors have been researched to a lesser degree and are often discussed at the level of propositions (i.e., proposed in various theoretical frameworks). At large, these factors can be grouped as follows: (a) *breadth of knowledge* (or *level of knowledge integration* necessary to undertake the project); (b) *geographic dispersion*, which also includes time zone differences and language differences (Cooke & Hilton, 2015; Salazar, Lant, Fiore, & Salas, 2012); and (c) *network connectedness* – the quality of networks that researchers and group have, as in Harvey, Pettigrew, and Ferlie (2002) and Salazar et al., (2012).

Team processes and emergent states. Recent literature on team science also underscored the importance of various team process factors that take place throughout different stages of research team development and are related to team effectiveness (e.g., Cooke & Hilton, 2015; Salazar et al., 2012; Salem-Schatz, Ordin, & Mittman, 2010). For instance, in Hall et al.'s (2012) framework noted in the preceding section, the authors highlighted the presence of specific team processes pertinent to each of the phases of transdisciplinary team-based research. Thus, the development stage is characterized by: (a) a shared mission and goals; developing (b) critical awareness and (c) group environment of psychological safety; and also (d) externalizing group cognition. According to Hall et al. (2012), in the *conceptualization* phase, the following team processes were important: (a) the development of shared mental models; (b) shared

language; (c) a team transdisciplinary orientation, and (d) compilational transactive memory. In turn, the *implementation* phase is characterized by: developing (a) compositional (who *does* what), taskwork (how things get done), and teamwork (how things occur) transactive memory; (b) conflict management; and (c) team learning. Lastly, the following team processes were pertinent to the *translation* phase: (a) the evolution of the team; and developing (b) shared goals for the translational endeavor and shared understandings of how these goals will be pursued. At the same time, my review of the literature suggests that Hall et al.'s (2012) list is not exhaustive and other processes have been cited as important in the literature, e.g., team cohesion, team efficacy, and team climate (Cooke & Hilton, 2015).

Some emergent stages have been also listed by team science scholars as relevant to the development of research teams. Emergent states are the "constructs that characterize properties of the team that are typically dynamic in nature and vary as a function of team context, inputs, processes, and outcomes" (Marks, Mathieu, & Zaccaro, 2001, p. 357). The following emergent states are often recognized in the team science literature: trust, shared team identification, psychological safety, and openness to diversity of perspectives and approaches. My reading of the literature suggests that scholars sometimes employ the same label for both processes and states, i.e., what one group of authors discusses as an emergent state, the other scholars can frame as a team process (e.g., *psychological safety* in Cooke and Hilton (2015) and Salazar et al. (2012)). In some instances, scholars did not make a clear distinction between a process and a state and labeled the phenomena rather general, e.g., as important *teamwork components* that play a role in the research team development (e.g., Salem-Schatz et al., 2010).

Organizational/Institutional Level. In spite of the recognition that "the relationship between a collaborative, interdisciplinary research project and its context is a key determinant to project success" (O'Rourke, Crowley, Eigenbrode, & Wulfhorst, 2014, p. 291), research on factors at the organizational and institutional level is limited (Cooke & Hall, 2015). Below I provide a brief review of the factors at organizational and institutional levels that have been connected to the success or failure of research collaboration across disciplines.

Existing university policies and discipline-based organizational structures are often recognized as one of key barriers for inter- (trans-) disciplinary research in the literature (DeBour et al., 2006; Cooke & Hall, 2015). To a great extent, this relates to tenure and promotion criteria in conducting disciplinary vs interdisciplinary research in universities. For instance, participants of a survey conducted by the National Academy of Science recognized promotion and tenure criteria as the uppermost impediment to interdisciplinary research (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2004). At the same time, as observed by Rhoten (2004), the incompatibility of university incentive and reward structures with interdisciplinary practices are often the "underestimated factors" when it comes to the practical aspects of facilitating interdisciplinary research in universities.

Insufficient organizational and technical support was also found as a factor hampering research collaboration (Kezar, 2005; Luo, Zheng, Bhavani, & Warden, 2010). In particular, Luo et al., (2010) discussed that difficulties with identification of compatible collaborators as well as insufficient organizational and technical support for complex data management tasks hindered the translational research project that the

scholars explored. In turn, Kezar (2005) illuminated a case when the introduction of a new accounting and computer systems allowed faculty and staff to collaborate on various aspects of cross-disciplinary research and teaching, including facilitating team-taught courses and joint appointments, and splitting indirect costs for research.

Barriers within the existing research culture were often found to be another impediment to collaboration across disciplines (Kezar, 2005; Luo et al., 2010). As Siedlok and Hibbert (2014) observed, "because the scientific characteristics of a discipline (such as epistemology and methodology) are not the only distinctive aspects – there are various symbolic resources, habits and other cultural accretions" that determine how professional (disciplinary) communities conduct their business (p. 204). Specifically, different disciplinary traditions often legitimate practices on how (and where) researchers share information as well as what is recognized as an accomplishment. For example, norms in many disciplines regarding assigning credit based on the order of authors' names are often in conflict when it comes to interdisciplinary publications (Cooke & Hall, 2015). In addition, traditional, highly ranked journals are often less interested in publishing interdisciplinary work (Rafols, Leydesdorff, O'Hare, Nightingale, & Stirling, 2012). Also, seeking funding for large-scale interdisciplinary research projects is often challenging, as national funding agencies have been traditionally organized to request and review proposals within a discipline-based organization.

In turn, *interdisciplinary research centers* have been often underscored as a factor that contributes to interdisciplinary collaboration (Cooke & Hall, 2015; Heitkemper et al., 2008; Kezar, 2005). Heitkemper et al. (2008) discussed a case in which they highlighted the interdisciplinary research centers' role in enhancing interdisciplinary research

activities by (a) consultation on research design and method; (b) development of core laboratory activities; and (c) mentorship of faculty and trainees. At the same time, as Bozeman, Fay, and Slade (2012) noted, there is still a lack of understanding on the processes and outcomes of research centers and institutions. In addition, the practice shows that many of already established centers that often carry labels as *college-wide* or *research* centers (which implies some *interdisciplinary* aspect of research collaboration), are, in reality, often "neither research-based nor college-wide" (Office of Research and Policy, CEHD, 2015).

Difficulties in sharing funding and intellectual property across institutions and countries are recognized as another barrier for interdisciplinary research. Despite recent advancements in technology that provide opportunities for researchers to collaborate across institutions and countries, working across different types of organizations and national borders, in addition to differences in languages and/or time zones as noted above, presents yet another challenge. As the report by the Australian Council of Learned Academies (Bammer, 2012) discussed, difficulties in sharing funding across institutions was a barrier to research collaborations, as "organizations tended to keep money to themselves, rather than bring in outsiders, who might have the most appropriate skills for some aspects of research" (p. 22). In addition, incompatibilities in funding and intellectual property mechanisms between different types of institutions (e.g., government research institutions, private organizations, and universities) were also seen as another barrier inhibiting research collaborations. When interdisciplinary research undertaking requires engagement of scientists (and organizations) from a number of countries, the

incompatibilities related to funding and intellectual property may even stronger jeopardize the scientists' efforts.

With regard to the institution-level factors, *policy settings* is another factor that may impede or enhance the work of researchers tackling complex societal problems that require expertise from several disciplines and areas of practice (Cooke & Hall, 2015). Although there has been a growing recognition in the literature that effective policy settings facilitate team science, scholars often complain that the existing policies to support and encourage interdisciplinary research can be best described as "muddling through" (Bammer, 2012). There is also an understanding that there is no single entity that can cope with all tasks necessary to promote and encourage team science. Several reports from different countries observe that, although the government is important player, other actors (such as private industry, non-profit organizations, philanthropies, and universities) have a stake in supporting and strengthening interdisciplinary research (e.g., Bammer, 2012; Cooke & Hall, 2015). In addition, there is an understanding that due to various legislative, historical, and infrastructure differences, national governments may require somewhat different strategies to determine and implement effective policy settings.

Summary

Below I list some points that illuminate the key areas where the proposed inquiry has a potential to contribute to our current understanding on interdisciplinary research teams.

As presented in this chapter, there are multiple factors at multiple levels of the system that influence researchers' choice and behaviors (Cooke & Hilton, 2015, p. 181).

Despite recent attempts to provide a taxonomy of the factors (e.g., Stokols, Misra, Moser, et al., 2008), these frameworks (a) have focused on research collaboration in general (without making a distinction between collaboration in teams and larger groups) and (b) often draw from literature reviews that are built on literature from *several* fields (including management and organization studies).

As will be highlighted in chapter 3, my review of the literature heightened my theoretical sensitivity to the studied phenomenon – factors that influence the work and progress of interdisciplinary research teams in the context of a public research university. Specifically, my reading of the literature also indicated that it was the *barriers* and not the *enablers* that had received most of attention in the literature. In addition to various intrapersonal and interpersonal factors highlighted in the literature, due to the literature review, I was also prepared to take efforts to explore various outside influences (at organizational and institutional levels) that impacted interdisciplinary research collaboration.

Chapter 3: Methodology

To answer my research question – *What are the factors that influence the work and progress of interdisciplinary research teams in the context of a public research university?* – I employed a multiple-case design (Eisenhardt, 1989a; Stake, 2006; Yin, 2014). This method of inquiry has been widely employed in organization and management studies (e.g., Gibbert & Ruigrok, 2010; Eisenhardt, 1989b). The method provides an opportunity to conceive a new (or advance an existing) theory (Eisenhardt, 1989a).

Within the case-study methodology, scholars distinguish between two general approaches to inquiry: (a) case-oriented approach and (b) variable-oriented approach (Miles, Huberman, & Saldaña, 2014). As Miles, Huberman, and Saldaña (2014) discussed, the case-oriented approach "considers the case as a whole entity – looking at configurations, associations, causes and effects ***within*** the case – and only then turns to comparative analysis of a (usually limited) number of cases" (p. 102). Using this approach, researchers "would look for underlying similarities and constant associations, compare cases with different outcomes, and begin to form more general explanations" (p. 102). In turn, the *variable-oriented* approach is theory-oriented from the start, where "the building blocks" are not cases, but rather certain variables and their interrelations. In this approach, a researcher would be "casting a wide net over a (usually large) number of cases" (p. 102). In the *variable-oriented* approach, "the details of any specific case recede behind the broad patterns found across a variety of cases, and a little explicit case-to-case comparison" is done (p. 102).

This study employed the *case-oriented* approach as approach to inquiry. As I was primarily interested in examining particular cases to answer my research question (i.e., interdisciplinary research teams on the interdisciplinary-to-transdisciplinary side of the continuum) as opposed to exploring some (pre-defined) variables and their interrelations in a number of cases, the *case-oriented* approach was selected. Specifically, this inquiry investigated four cases: four interdisciplinary research teams working on innovative research projects.

What follows is a detailed discussion of data collection and data analysis procedures and processes.

Data Collection

Selection of cases. As the focus of the study was on interdisciplinary research teams that had a high potential for innovation and were also transcending some pre-existing disciplinary boundaries in their research, I implemented a purposeful, two-stage selection of cases. First, I identified 43 cross-disciplinary research teams that were recognized as inter- and/or transdisciplinary research teams by the university community. After approaching the teams' primary (co)-investigators via email and learning about their research projects, I narrowed the pool of teams to twelve research teams. Second, I interviewed primary (co)-investigators from the twelve teams, and, based on the interviews and the data the researchers shared about their projects, I selected four research teams for my study. The following two sections discuss the selection process in details.

Selection of cross-disciplinary research teams. To identify interdisciplinary research teams working in the context of a public research university, I sent out emails to various researchers, affiliated with the University, and also to academic and research units of the University (See Appendix E). Specifically, I sent out emails to the following contacts:

a) Relevant contacts that I established in my exploratory study and during the four Grand Challenges Research Forums at the University;
b) Fifteen interdisciplinary research centers at the University and the Office of Interdisciplinary Research at the Graduate School;
c) Associate deans with responsibilities for research in five colleges.

In the emails, I outlined the nature and purpose of my inquiry and asked addressees to provide contact information for primary (co)-investigators working on cross-disciplinary research project(s) where science and/or engineering was an important component. Upon receipt of responses, I created a list with the contact information of prospective candidates and sent out invitations via email to each of the candidate with a request to participate in the first round of the study (See Appendix F). After checking with the referred researchers their availability to participate in the study, I analyzed the information that they provided in their responses (in relation to the guiding research question), while looking for the teams where science and/or engineering was an important component. Based on my analysis, I scheduled and conducted 12 interviews with primary (co)-investigators working on different interdisciplinary research projects.

Selection of the four cases. The selection of the four cases was based on my interviews with primary (co)-investigators and analysis of their project information that they provided during the interviews (whereas applicable). For the interviews, I employed a semi-structured interview instrument developed based on my exploratory study (See Appendix H). During the interviews, researchers were asked about their research teams' objectives, team members' field expertise and affiliation, time-frames and support structures of their research projects. I also sought to learn about the historical development of each team (how it emerged and developed), how things get done, how interactions occur in the collectives, and what external and internal factors influenced their teams' work and progress. Each interview lasted about 50-60 minutes. Each of the interviews was recorded and transcribed.

Based on the interviews, a summary sheet with the description of twelve research projects was created. Subsequently, all research projects were reviewed with regard to certain criteria, including: (a) the presence of researchers from different disciplines (departments); (b) research objectives and team's progress made to-date with regard to achieving these objectives; (c) research team's potential for innovation (as discussed by the informants and/or stated in their project documentation; competitiveness of the grant application process (if indicated by the funding sources); (d) the publicity the project has received (based on my online search), including awards and accolades, whereas applicable; and (e) the number of team members and relatedness of the disciplines the team members represented. No scoring system was used at this stage. I was also looking for established teams, i.e., collectives who had clear understanding of who was on the team, who had defined objectives, and who could be characterized by a medium-to-high level of interdependence among team members.

While selecting teams for the inquiry, I sought to obtain a balanced sample of cases, in which issues and processes could be compared, but in which there was also some heterogeneity with regard to teams' support structures (type of funds), team members' field expertise and affiliations, and research problems the teams were working on. As group size is recognized as an important variable in team research, I also sought to select cases that were comparable with regard to their sizes. In particular, following Cooke and Hilton (2015) who distinguished between "science teams" (two to ten individuals) and "large groups" (more than ten individuals), collectives with up to ten individuals were given my primary consideration. As somewhat different factors may affect the work and progress of research teams depending on their development phase

(Hall et al., 2012), I also purposefully selected research teams that were in somewhat different phases of carrying out their research projects.

Based on the aforementioned criteria, I identified four teams to further investigate in the inquiry. Table 2 presents a summary of the four teams that the study explored. For the purpose of keeping teams' identities confidential, each team is assigned a code name in the table: Team A, Team B, Team C, and Team D.

Insert Table 2 about here

All four teams were pursuing different research objectives. The first team was working on the identification and study of new antifungal medication to treat fungal infectious diseases. The team aimed to study and produce antifungals from natural products, as current drugs are very toxic. The second team was working on the development of compression garment that uses shape-changing materials integrated into the garment to provide controllable, on-demand compression. This garment was seen as a solution for patients with illnesses where compression can be a part of treatment. The third team was testing feasibility and design of a new medical device for stroke rehabilitation. This device employed a noninvasive transcranial direct current stimulation (a form of brain stimulation via electric signals). The espoused, post-stroke recovery was expected to combine this form of brain stimulation with hand exercises, with the delivery of the rehabilitation services conducted over the Internet. The fourth team was working on the development of chemically recyclable bio-based polyurethane foams. Their

research was also innovative as conventional polyurethanes (foams) are petroleum-derived and are non-degradable.

The four teams were scheduled (or had been performing) their research activities in different locations, both at the university facilities and outside. Thus, one team was using on-site facilities for product design and team meetings, while trials were to be carried out in a clinic located in a different city. Two teams were using on-site facilities to carry out their research, while the other team was scheduled to perform trials both on-site and outside of the University (via the Internet).

Investigation of Four Cases. To collect my data, I conducted interviews with 12 informants from the selected cases, observed several team meetings and training sessions held by the teams, and collected project documentation. As a result, three types of data were obtained: interview data, observation field notes, and research project data.

Interview data. Overall, I conducted 12 interviews: in addition to the interviewed senior researchers (during the selection of cases), two other informants were selected and interviewed from each case. While selecting informants from each team, I sought to obtain data both from senior researchers (primary (co)-investigators) and other team members (e.g., graduate students working on the projects). In addition, as I sought to obtain data at somewhat different time points of the research projects' implementation, I purposefully scheduled some interviews around important events (e.g., a trip to a project site or a training session). After collecting interview data from three informants from each case, I felt that having another interview would not yield additional information about their cases, and I have obtained sufficient interview data to answer my research question.

All formal interviews were semi-structured and took from 45 to 75 minutes. For these interviews, I employed the same semi-structured interview instrument as for my interviews with PIs (Appendix H), with some minor adaptations of some questions in order to discuss the most recent event(s) and/or better reflect the nature of each research project. All formal interviews were tape-recorded and transcribed.

Observation field notes. In addition to conducting interviews with team members, I also conducted several observations. In particular, for one case, I attended and observed two team meetings: (a) a team meeting that took place before one of the trips to the project site; and (b) a meeting that took place after their (final) trip to the site, before the team was scheduled to resubmit their application to obtain the second part of grant. For another case, I observed: (a) a training session during which the researchers were practicing the method before a trial (with focus on how to use equipment and coordinate their efforts in the process); and (b) an actual trial with a real patient. In two other cases, I was given a tour to explore their teams' lab facilities. During the tours the researchers explained what activities were carried out and how they organized their work.

No formal interviews were conducted during field observations. At the same time, when I came across issues that required clarification, I typically followed up with informal questions and noted relevant information. With permission, I was also able to examine and take photos of the equipment used, as well as various samples and/or prototypes of the products developed during the projects' implementation (in relevant cases).

While doing field observations, I collected a great deal of data in the form of field notes. According to Saldaña (2014), field notes are "the researcher's written

documentation of participant observation, which may include the observer's personal and subjective responses to and interpretations of social action encountered" (p. 45). Thus, in those instances where I was able to observe actual interactions (during team meetings and trials), I took extensive notes on what was happening during the event and how the team members were interacting with each other. After each observation event, I also purposefully allocated time to reflect on my notes and also on what I had observed, and took additional memos. Not only did the notes and memos provide data for the subsequent analysis, in some instances they also aided with formulating more penetrating questions in the interviews that took place after the observation events.

Project documents. In addition to interview data and observations of project-related events, various relevant documents and team artifacts pertinent to the focus of the inquiry were collected and analyzed. These documents and artifacts contained a wide range of items, including those that the participants were willing to share, as well as those found on the Internet (primarily those published by granting agencies). These items varied from team to team and included some of the following: applications for grants and/or abstracts (as submitted to obtain grants); researcher manuals developed during project implementation, photos of prototypes developed in the project implementation, conference papers, and also a journal publication. The internet search for the project-related data available online also resulted in a number of documents that provided additional information for analysis. These documents included various college/departmental news items showcasing the teams' achievements, information on the institutions that issues grants, or publications by the institutions featuring the teams as grant recipients. The identified documents served as secondary sources for analysis,

aiming to provide deeper understanding of research activities performed by the selected teams.

While collecting data from all three sources – interviews, field observations, and project documents – I kept writing notes and memos. These notes and memos provided additional insights during my data analysis. I kept collecting data until I recognized certain patterns and no additional data appeared to be contributing to the refinement of the main concepts derived from the data analysis.

Data Analysis

Data analysis was conducted with consideration of the guidelines provided in seminal works on qualitative data analysis (e.g., Miles, Huberman, & Saldaña, 2014; Saldaña, 2015; Yin, 2016) as well as in the studies discussing the methodological aspects of case study research (e.g., Gibbert & Ruigrok, 2010; Eisenhardt, 1989a; Yin, 2014). What follows is a more detailed review of the steps undertaken in the data analysis.

In line with Miles, Huberman, & Saldaña (2014), initial data analysis took place at the time of data collection. For instance, some initial coding ("pre-coding") took place *as* data were transcribed, i.e., when a researcher highlights, bolds, and/or underlies significant informant quotes that appear worthy of attention (Saldaña, 2015). In this inquiry, such quotes either related to some characteristics of a team (e.g., team members' expertise and affiliation) or shed light on some issues that influenced the work and progress of the teams. Similarly, some initial analysis also took place while selecting the four cases for the inquiry, when brief case reports were created for the identified cross-disciplinary teams. This analysis was partially aided by the aforementioned "pre-coding" step.

As the research design employed both within- and cross-case analyses, coding electronically (i.e., using Computer Assisted Qualitative Data Analysis (CAQDAS) program software) as opposed to manual coding was selected as a primary means to code (and analyze) data. Lewin and Silver (2007) noted the following benefits of using a customized CAQDAS package: (a) organizing the data, (b) organizing ideas about the data, and (c) interpreting the data and convergence of data interpretations within the CAQDAS container. Electronic coding also provides a researcher with a greater ability to shift back and forth between various analytic tasks (coding, memo writing, and exploring emerging patterns), as well as running searches and queries in the data (Saldaña, 2015). In this inquiry, I employed the NVivo for Mac software for coding and analyzing the collected data. Prior to using the software, I attended several NVivo workshops at the University and also completed the online NVivo for Mac tutorial provided by the manufacturer.

Yin's (2016) framework for qualitative data analysis served as the main roadmap for conducting data analysis (See Figure 1 below). Yin (2016) suggested the following five (interrelated) phases of data analysis: (a) compiling, (b) disassembling, (c) reassembling, (d) interpreting, and (e) concluding. During data analysis, a researcher is expected to move back and forth between some phases multiple times (as the two-way arrows suggest). As the study employed a multiple-case design, I also conducted within-case and cross-case analyses (Eisenhardt, 1989a), before reaching the "concluding" phase.

Insert Figure 1 about here

Compiling Data. Prior to analyzing the data, I compiled and arranged in proper order key sources used in the study: transcribed interviews, notes from field observations, and memos. Following Saldaña's (2015) and Miles, Huberman, & Saldaña's (2014) guidelines, I paid attention to preparing interview transcripts for my analysis in NVivo. In particular, I broke the text into meaningful units (paragraphs) and ensured that the texts were formatted appropriately. Similarly, I reviewed my field notes and memos and prepared them for uploading into NVivo. Before entering relevant sources into the software, I assigned new descriptive names for each source, which characterized them by type (e.g., interview, field observation, or memo), time created, respective cases, and informants (for interview transcripts). Once uploaded into NVivo, each source in the software was classified based on the type of source and also assigned to one of the respective four cases (teams).

Disassembling Data. The disassembling procedure involves breaking down data into smaller pieces by assigning new labels or codes (Yin, 2013). While coding my data (Initial, Level 1 coding), I primarily used one of the following methods: Descriptive Coding, In Vivo Coding, and Process Coding. According to Miles, Huberman, & Saldaña (2014), "a descriptive code assigns labels to data to summarize in a word or short phrase – most often a noun – the basic topic of a passage of qualitative data" (p. 74). In Vivo coding employs "words or short phrases from the participant's own language in the data

record as codes" (p. 74). In turn, Process Coding "uses gerunds ('-ing' words) exclusively to connote observable and conceptual action in the data" (p. 75). In some instances, I applied two or more different codes to a single datum (when the content suggested multiple meanings). As the process of coding continued, some codes were revised, and new codes appeared. As noted by Miles, Huberman, & Saldaña (2014), "some codes do not work; others decay. No field material fits them, or the way they slice up the phenomenon is not the way the phenomenon appears empirically. This issue calls for doing away with the code or changing its type" (p. 82). In the process, several broader categories (Level 2 or "parent" codes) also began emerging.

In the process of coding data, I was taking analytic memos. Miles, Huberman, & Saldaña (2014) defined an analytic memo as "a brief or extended narrative that documents the researcher's reflections and thinking processes about the data" (p. 95). In addition to creating memos that contained preliminary interpretation of the data pertinent to my main research question – *What are the factors that influence the work and progress of interdisciplinary research teams in the context of a public research university?* I also created separate memos for each case. These memos contained verbatim quotes from respective researchers (with regard to their projects) and provided answers to the so-called reporter's questions: Who? What? When? How? Why? These memos became helpful in writing of summary sheets for each of the studied cases (for the within-case analysis).

Reassembling Data. As the number of codes grew, I started arranging the codes in different arrays, while looking for common patterns across the data. In the process, I was using various techniques, including *creating hierarchical arrays* and *designing*

matrices as arrays (Yin, 2013). The usage of the NVivo software aided my analysis as it provided additional options to create various visual displays. For instance, I used the "Explore Diagram" function as it allowed controlling for the display options, e.g., showing lower-level categories ("children" nodes) but not sources coded. In addition, the "Compare Diagram" function was used to analyze those codes that were shared between two (selected) cases (or two informants within the same team). In addition to using the software, I was also performing manual operations, while sketching various interrelations between the emerging broader categories, their sub-themes, and the possible relationships between them.

Similar to the previous phase, I kept taking analytical memos that reflected my thinking on the emerging broader categories (e.g., their frequency or intensity in the studied cases, how they were related to the main question of my inquiry, etc.). As a result of the data reassembling, five broad groups of factors emerged, with four groups somewhat consistent with the literature and one group of factors that warranted further exploration of the data. Following Yin's guidelines (moving back and forth between the phases of analysis), I performed the second cycle of coding, during which I further shaped the identified categories (factors) and also reviewed all data with a focus on the emerging categories.

The primary methods for my second cycle of coding can be broadly described as "Focused Coding" and "Pattern Coding." According to Saldaña (2015), when using focused coding, researchers search "for the most frequent or significant codes to develop the most salient categories in the data corpus" and need to make decisions about which initial codes make the most analytic sense (p. 240). This type of coding, the author noted,

is particularly appropriate for the development of major categories and themes from the data. In turn, pattern codes "pull together a lot of material from the first cycle of coding into more meaningful and parsimonious units of analysis" (Saldaña, 2015, p. 236). Saldaña (2015) compared this method to the factor analytic devices employed in statistical analysis. While it can be applied for various purposes, this type of coding also lays the "groundwork for cross-case analysis by generating common themes and directional processes" (p. 236). At this stage, I was also paying close attention to analytic memos, field observations notes, and project documents.

Within-case and between-case analysis. As discussed above, the study design utilized the *case-oriented* approach toward data collection and analysis. The case-oriented approach "considers the case as a whole entity – looking at configurations, associations, causes and effects ***within*** the case – and only then turns to comparative analysis of a (usually limited) number of cases" (Miles, Huberman, & Saldaña, 2014, p. 102).

While performing within-case analysis, I thoroughly studied data from interviews, field observations, and project documents that belonged to each of the respective case, and also created detailed summaries with the description of each case. In the process, I employed relevant memos and notes that I had created at earlier stages of analysis (e.g., memos containing verbatim quotes from the respective informants from each case). With the help of the NVivo software, I also utilized various data presentation methods to analyze the extent to which some particular factors (nodes) were evident in the selected cases. I was looking for both the relative frequency with which different factors were

noted by respective informants as well as the intensity with which the informants described those factors.

While performing cross-cases analyses, I was looking for the underlying similarities and differences across the four cases with regard to important factors that influenced the work and progress of the examined teams. In the process, I employed various techniques and tools for data presentation and analysis. For instance, using the "Comparison Diagrams" tool in the NVivo software (the tool helps to visualize coded nodes of *two* cases of interest), I explored the similarities and differences in (selected) two teams of interest with regard to the presence or absence of some factors. In addition, I employed the "Matrix Coding" tool for the analysis of selected categories across the *four* cases. The analysis of matrixes provided additional insights on which factors were pertinent to particular cases.

The within-case and between-case analysis resulted in further refining, eliminating, and/or expanding of some categories, to better reflect the meaning of the data, when assessing the data across all four cases.

Threats to Validity and Tactics to Enhance the Quality of the Study

As I conducted a review of the literature on the topic prior to collecting and analyzing data, I acknowledged that there could be some *researcher bias* on my side – "the selection of data that fit the researcher's existing theory or preconceptions and the selection of data that 'stands out' to the researcher" (Maxwell, 2005, p. 108). I sought to address this threat to validity by reflecting on my perceptions of the studied phenomenon in analytic memos ("rich data"). In addition, I employed three more strategies – *triangulation*, *feedback*, and *comparison* – to avoid this and other possible threats and to

test the validity of my conclusions (Maxwell, 2013). Below I provide a brief summary of each of the tactics.

"Rich data." Verbatim transcripts of interviews and detailed memos that I wrote during/after interviews and field observations provided a rich, detailed grounding for my conclusions.

Triangulation. Triangulation implies using multiple methods or data sources to develop a comprehensive understanding of phenomenon under investigation. In the study, I employed two types of triangulation (a) method triangulation and (b) sources triangulation.

Method triangulation. I employed three methods to collect my data: interviews, field observations, and document analysis. By collecting interview data, observation field notes, and project data, I attempted to counterbalance flaws that might have been evident had I employed a single method.

Sources triangulation. While collecting data, I purposefully sought to obtain data from different types of informants (e.g., tenured and tenure-track faculty members, doctoral students and master's students).

Feedback. Throughout the study, I solicited feedback from informants (researchers) regarding my interpretation of their cases (e.g., by following up on some issues that were not clear and by soliciting feedback on the summaries of those cases that required further information and/or clarification).

Comparison. As the research design envisaged a multiple-case study approach, four cases of research teams were compared throughout the study. By comparing several

cases as opposed to a single case, I also strengthened (analytical) generalizability of my conclusions so they could be applied to a wider range of similar cases.

In turn, my personal experiences as a doctoral student, working in the same research university as some of the study informants, strengthened my theoretical sensitivity for data analysis. Hannah and Lautsch (2010) discussed theoretical sensitivity as researchers' quality that allows researchers being aware of meanings in the data. The authors suggested that researchers develop theoretical sensitivity by "being aware of relevant literature and by having direct experience with a phenomenon of interest" (p. 20). In addition to my research experiences as a doctoral student, the literature review conducted for the inquiry and presented in chapter two also broadened my familiarity with some of the central themes that emerged from my data analysis.

Confidentiality and Protection of Human Subjects

Prior to conducting the study, I sought approval from the Institutional Review Board, which concluded that the planned activities did not fall under the IRB's purview. While I was not required to obtain informed consent from participants, all interview participants were provided with a letter that documented their rights as a participant and my responsibility as a researcher (Appendix G).

Although IRB did not recognize the research informants as a vulnerable population, I endeavored to maintain their confidentiality and also protect my data. Specifically, I kept all study recordings on my password protected electronic devices. I used the initials of the participants instead of their full names in my field notes and interview transcripts, and also while conducting analysis in the NVivo software. I also used pseudonyms instead of real names, while reporting my findings.

Summary

The Methodology chapter discussed the multiple-case research design employed in the study. Using a two-stage sampling of cases, I identified and collected data from four interdisciplinary research teams. I performed my data analysis, which entailed within- and between-cases analysis, using the NVivo software. In the process of the study design and implementation, I was mindful of and sought to address several threats to validity of my conclusions. What follows is the Findings chapter that reviews the key findings resulting from the analysis.

Chapter 4: Findings

The main research question guiding the study concerned the identification of key factors influencing the work and progress of interdisciplinary research teams in the context of a public research university. The data collected and analyzed in this study revealed the presence of multiple factors that impact interdisciplinary, university-based research teams. The study findings addressing the main research question are depicted in the model shown in Figure 2 below.

The multiple-case research design employed in the study and the literature review, reported in chapter 2, provided me with deep insights on the concept of "interdisciplinary, university-based research team" as a distinct form of human systems situated in a particular context. Informed by the rich contextual data, I propose three theses that, together with the model, shown in Figure 1, are the building blocks of the emerging, mid-range theory on interdisciplinary, university-based research teams. I elaborate on the three theses and also outline some propositions to further confirm (or disconfirm) the mid-range theory in Chapter 5.

First thesis. *Interdisciplinary, university-based research teams are open systems that adapt and evolve as new research opportunities and situational demands unfold.*

Second thesis. *The work and progress of interdisciplinary, university-based research teams is a function of multiple interacting factors situated at different levels of analysis (including individual, team, organization, and institutional levels).*

Third thesis. *The work and progress of interdisciplinary, university-based research teams is contingent on diversity in expertise, social integration, and project management capacity of the teams.*

In this chapter, I start with an overview of the model presented in Figure 2. The overview aims to provide an overall perspective (the big picture) on the factors influencing the work and progress of interdisciplinary, university-based research teams. My subsequent discussion of the factors is organized according to the major themes that emerged as a result of data analysis. As noted above, Chapter 5 will provide a detailed discussion on the three theses and the propositions that set directions for future research.

Model Overview

Insert Figure 2 about here

The model in Figure 2 indicates that the work and progress of interdisciplinary, university-based research teams is impacted by multiple factors, which are grouped under five broad groups. Four groups of factors derived from the data analysis – *individual-*

level factors, *team-level factors*, *organization-level factors*, and *institution-level factors* – were to a large extent similar to those discussed in the literature on interdisciplinary research. In turn, one group of factors – *project management aspects of managing funded projects* – was the theme that has received only some attention in the literature (with the exception of the *funding* factor). While most of the factors appear rather neutral and may characterize any collective undertaking where the goal is knowledge production or innovation, when the context (a public research university) is taken into account, certain characteristics (properties) that the factors possess, as the study findings suggest, may impact the work and progress of interdisciplinary, university-based research teams in unique ways (e.g., enabling or hampering the team's research).

What follows is the review of the key factors and their characteristics organized according to the major themes and substantiated with relevant quotes from the interviews.

Individual-Level Factors

Data analysis resulted in identifying six important factors, at the individual level of analysis, which influenced the work and progress of interdisciplinary research teams. The six factors were: (a) motivation; (b) connections and networks; (c) personality; (d) prior assumptions; (e) status of team members, and (f) busyness. All six factors were present in the majority of the interviews. Below is my description of the factors and their characteristics.

Motivation.

> …having these projects, with a broad scope, in fact, can be a real magnet for some of our very best students to engage in, which is a huge plus. Because when they

have that inherent interest in the project, then they're automatically going to do a good job.

Senior Researcher

During my data collection, it became apparent that the researchers were highly motivated to work in the examined research projects. In their interviews, the informants often employed the words "purpose," "(inherent) interest," or "passion" when discussing their research projects and/or explaining why they were engaged in their research activities. An analysis of the interview data revealed the presence of the following motivators that contributed most to the work and progress of interdisciplinary research teams: (a) practical importance of work; (b) learning opportunities; and (c) career opportunities (primarily for junior researchers). While other motivators were also mentioned (e.g., "a nice prize"), these three motivators appeared most often in the interviews.

Across all four cases, the informants were driven towards achieving their research objectives that, in all four cases, underscored practical implications of research results (e.g., improved healthcare treatment, sustainable environment). The practical importance of research was noted by the informants as a strong motivator for conducting interdisciplinary research. While addressing real-life issues (i.e., finding a solution to an important practical problem) was pivotal for researchers, some informants also noted that practical results were also of great interest for other stakeholders (e.g., venture capitalists, funding agencies). As a result, once researchers were able to demonstrate the practical importance of their work, then more opportunities appeared to sustain and/or scale up their research activities. As one of senior researchers discussed:

> Is the consequence of that activity a new and improved therapy option for patients? Is the consequence of that activity a new way an anesthesiologist can think about while doing things in the operating room? So, I get you're working on it, but show me the results… In my mind, that is where visibility comes from. And, also, the part that triggers further interest, ether be it from a venture capitalist looking to put money into a start-up company that is resulting from it, or NIH, choosing to fund a larger research project, or whatever…

In addition to some practical benefits of interdisciplinary research, informants consistently noted that the research projects provided various learning opportunities for team members, and these learning opportunities appeared to be another motivator contributing to the work and progress of research teams. For instance, while researchers were highly motivated to learn about the phenomenon they investigated, other learning opportunities, such as learning about technical aspects of using some technology, or how to work in interdisciplinary research teams, were often mentioned in the interviews. As discussed with several junior researchers, the researchers often took extra efforts (at the expense of their own time) to learn about various aspects of their research projects that were new to them (and sometimes beyond their direct responsibilities). In several instances, these extra efforts have led to a better understanding of some possibilities and/or limitations of their team's approach in conducting research. For instance, in one case, a student took an initiative to further explore some (technical) nuances of the technology employed in their project, which resulted in a better understanding of some specifics of the research equipment and also led to altering some of the team's goals.

Career opportunities was another motivator (primarily for junior researchers) that contributed to the work and progress of interdisciplinary research teams. Specifically, junior researchers were highly motivated to gain experiences in those areas of research that aligned mostly with their career aspirations. Once there was a fit between researchers' responsibilities and career aspirations, the researchers were often reported to demonstrate a higher level of engagement that facilitated the work and progress of their research teams. The career opportunities factor was particularly evident in the student-led research project. As all three interviewed researchers observed, throughout their project implementation, team members were putting more "energy" into those aspects of their project (e.g., communicating with the industry, writing a scientific publication, or working on a provisional patent application) that aligned more with the researchers' skill-sets and career aspirations. What is noteworthy, by the end of their research project (submission of a provisional patent), several researchers on the team had received job offers in those areas of research and practice that they had an interest in or, in fact, started considering during their project implementation.

Connections and networks.

> [Collaborations] are sort of organic. And they're through connections and networking, and when you have a project, you think, "Oh, I should reach out to this person."
>
> Senior Researcher

Data analysis revealed that *connections and networks* that researchers brought to the projects played an important role in the development and implementation of their research projects. Specifically, the *connections and networks* factor was found to be

influencing the work and progress of interdisciplinary research teams in three important ways: (a) facilitating the team formation; (b) enabling research teams to promptly respond to new research opportunities; and (c) providing access to additional resources during implementation of research projects.

As noted by several informants, core members of their research teams either had known each other through researchers' affiliation with the same research center or, in fact, had previously collaborated on joint research projects. These connections appeared to be facilitating the formation of new research teams. As one of the researchers observed, "…the barrier to forming a team was really low, because we already knew each other and had worked together on projects." In addition, "connections and networks" were found to enable researchers to promptly respond to new research opportunities (e.g., calls for proposals). Thus, researchers with connections and networks appeared to be rather efficient in forming collaboration with other researchers possessing complementary expertise. For instance, as it became evident in one case, when researchers who knew each other through their work in a research center found about a prestigious research competition they could enter, the researchers were able to prepare and submit a (winning) research proposal on a short notice. As one of the researchers reflected on their team's experiences, "So, when we saw this competition, we wanted to work together, because we really liked each other and we knew we had complementary skill sets."

The existing connections and networks also appeared to be a source of acquiring additional resources (e.g., ideas, feedback, and materials) that the team could employ in the process of carrying out their projects. For instance, when the student research team

was tasked to prepare a business pitch for a for-profit company, researchers used their connections and reached out to several experts from the targeted industry to obtain feedback on their presentation. As noted by one of the informants, this experience was "really helpful, 'cause they gave us more like [company's name] culture critique." Therefore, researchers' connections and networks contributed to the work and progress of their research team.

Personality.

- The idea that people can really work together. What does that mean? You'll be like "I'm a nice person, you're a nice person."
- "Let's work together."
- "Well, let's work together. That's gonna be a great project!" And that's not always true. And I've had terrible collaborations, terrible.

Senior Researcher

In all four cases, informants noted that certain personal characteristics were more suitable than others for interdisciplinary research projects. After data analysis, two general types of personal characteristics became apparent: (a) attitudes and behaviors contributing to collaboration on projects, and (b) attitudes and behaviors working against it.

Among those characteristics that contributed to the work and progress of research teams, the following were reported: "*willingness to listen*," "*willingness to share what one knows*," "*willingness to share the work and share the outcome*," "*being humble*." In their interviews, several informants noted that they enjoyed collaborating with those researchers who possessed the aforementioned characteristics. Many of researchers also

observed that they had been friends with some of their team members prior to their collaboration in the examined research projects, or they became friends in the process of carrying out their research projects. As one of the informants reflected on his experiences with one research group, "You know, I enjoyed just hanging out with them… we've become friends."

Among those personal characteristics that hampered collaborative efforts, the following were discussed: "*big personality*," *having an ego*," *being "so wrapped up in [engineering] role" and not knowing how "to speak about what they do in a more generalizable way."* The following excerpts from two researchers' interviews showcase some of the characteristics and their influence on the work and progress of interdisciplinary research teams:

> And the other thing that can happen is when you get people who have an ego and people who…when something gets really interesting they wanna take it. You know, "This is really *my* idea. Thank you very much but I'm gonna work on this now"… And it does not allow you to really further the project in an actually collaborative way. So, it's something that I've learned through collaborations that people need to be a little bit humble. They may need to have some humility and be willing to share the work and share the outcome.
>
> …
>
> I've been on some teams, where it's been nearly impossible to get things done because people, certain people, have very big personalities. And they're very set on what it is that they do, that's the right way to do it…

As illustrated in the above excerpts, having an egotistical and/or self-interested personality was reported as hampering interdisciplinary research. In turn, researchers' willingness to share the work and the outcome was a personal characteristic that was perceived as facilitating the work and progress of research teams.

Prior assumptions about other members' knowledge and skills.

> I'd say that was really a big learning curve for me. I was shocked, honestly, the first couple of times, 'cause I've only been surrounded by engineers… The only PhD people I knew were engineers, and so, when I was like, "Oh, Dr. Steven is a PhD, this will be easy!" No, it was not! (laugh).
>
> Junior Researcher

Another factor that influenced the work and progress of interdisciplinary research teams was prior assumptions that team members held about other members' skills and knowledge. This factor was evident in two cases, and in both cases it was junior researchers who held (faulty) assumptions that their collaborators would possess the right skills and knowledge (which were rather foundational (basic) in their respective disciplines). As it became evident in both cases, prior assumptions about other members' skills and knowledge led to certain delays in the projects' implementations.

For instance, as noted by two junior researchers in one of the examined cases, when they asked the staff in the clinic to provide them with the measurements of people participating in a trial (held on a site located in another town), the measurements turned out to be "narrower."

> We need to make sure that our garment fits everyone… So, we were gonna have them [staff in the clinic] measure them. But, actually, Robert gave us the

measurements narrower, so we figured it out that he didn't measure them correctly. So, I guess we assumed that he would know how to measure people, but he didn't know that. So, we should have done that, when we were there.

When coupled with other factors (e.g., distance), holding assumptions about other members' skills appeared to be a significant factor hampering the progress of research projects. Thus, in the case presented above, once the researchers realized that the measurement was incorrect, the team had to take additional time to develop new garments with proper sizes for their trial, and was able to schedule a trip to the project site only three weeks later.

Noteworthy was also the fact that, in the two cases where this factor was evident, researchers were quick to acknowledge their (faulty) assumptions and took efforts "to teach" the other collaborator(s) the required skills and/or took actions to avoid similar occurrences in the future.

Status.

Data analysis also revealed that researcher's status appeared to be another factor that could impact the work and progress of interdisciplinary research teams. Thus, the analysis of the interview data revealed that there were differences in opinions how the informants assessed the availability of resources for interdisciplinary research and the process of interdisciplinary research evaluation depending on their status: (a) a tenured professor; (b) a tenure-track professor; and (c) a student.

Amongst the faculty, the perceptions on the availability of resources ranged from being "not a problem" and "easy" on the side of tenured professors to "competitive" and "challenging" on the side of tenure-track professors. In terms of students, the latter

expressed great appreciation for the resources they used and for the career opportunities that the research projects offered for them in the future. At the same time, junior researchers also noted that, although highly motivated to do interdisciplinary research, students in their programs often do not know what opportunities for interdisciplinary research are available, where to obtain the information on such opportunities, or how things are organized at the department (or college) to access available resources: "I just wish there were more instances of… when they would help connect students to other disciplines, so to speak."

Similarly, while tenured professors appeared to be less worried about who evaluated their research – "once you have tenure, which I do, then who cares what your peers think about you," evaluation of interdisciplinary research appeared to be of higher concern for tenure-track professors. At the same time, several interviewed faculty members [primarily in engineering] seemed to agree that conditions for interdisciplinary research have been improving for junior faculty over recent years. As one of the interviewed tenured professor noted, "Now when we evaluate people for promotion and tenure, there's much more of an openness to recognizing that there's different norms for succeeding academically."

Busyness.

> Professors are busy, clinicians are extremely busy, finding time to get together to talk about the project and to have these planning meetings, matching up to extremely different schedules is a challenge.
>
> Senior Researcher

The word "busy" was frequently mentioned by informants in their interviews and also captured during my observations of research teams' meetings. As it became apparent, across all four cases, the interviewed researchers were engaged in multiple activities, of which the examined research projects were only one of several. Thus, in addition to conducting research, faculty members performed other responsibilities (e.g., teaching, advising, serving on committees, etc.). As was found in several cases, the busy schedules of researchers appeared to be hampering the work and progress of their teams. For instance, as a senior researcher commented below, researchers' busyness was the reason why his team delayed the implementation of their research project:

> I guess the only complication is that he [another researcher] is so busy that sometimes it goes slower than I wanted it to go. So, that's why I'd like it to get started in June or July, but he's talking September, October. So, it keeps getting pushed a bit later and later because he's so busy.

While senior researchers were expected to be engaged in teaching and service, in addition to research, junior researchers were expected do well in their studies: to prepare and attend classes, work on class assignments, etc. Balancing time for school and the respective research projects was often reported by junior researchers an issue that they had to deal with. Lastly, as suggested in the excerpt to this section, when the scope of research projects involved representatives both from and outside of academia (from other industries), "matching different schedules" was quite challenging for collaborators. In such collaborations, "busyness" was also found to be a factor hampering interdisciplinary research projects.

Team-Level Factors

Data analysis also revealed five important factors influencing the work and progress of interdisciplinary teams related rather to a collective, not just an individual. In particular, the following team-level factors were evident in the examined cases: (a) open communication; (b) reflexivity and learning; (c) balance in team members' expertise and input; and (d) shared purpose.

Open Communication.

> It's important that we … can easily communicate, that we can really hear what we're all saying and understand it. Some collaborations don't work that way. In some collaborations you're technically working together, but you are both very separate, and *you* have an idea what's important and *you* [another person] have an idea what's important. And you're [together] just doing two separate things.
>
> Senior Researcher

Open communication among team members was found to be an important factor contributing to the work and progress of interdisciplinary research teams. In all four cases, informants highlighted that conducting research at the intersection of various disciplines required open communication between team members, as researchers often have to deal with the issues where they have only some (or no) experience. This idea is well-illustrated by the excerpt from an interview with a researcher in the apparel field: "The stuff that we're doing on the medical side, a lot of it, it just can become confusing without talking with them [medical staff] there – it makes it much clearer what's going on. I've read about it, but it makes a difference talking about it."

The degree to which team members could (or could not) openly ask questions related to research was one of central concepts within the "open communication" theme. In particular, research contexts in which "people are not feeling comfortable asking questions, or feeling like their ideas would be stupid because they aren't experts in whatever field" were seen as hampering the work and progress of interdisciplinary research teams. Similarly, research contexts in which the researcher "felt more comfortable approaching [engineers]" and asking for clarification on some concepts were seen as conducive to interdisciplinary research.

Similarly to asking questions, the "open communication" theme also entailed an idea of team members being attentive to other members' opinions, considerations, and feedback. As one of the informants observed, "In my experience people who work truly collaboratively are really listening to each other and working together very deeply." This component was particularly evident during my field observations of research meetings. During the meetings, both students and professors were making suggestions on how to approach particular research-related issues. In one of the meetings, when a student shared an (innovative) idea regarding some design options that the group was discussing, both professors present at the meeting recognized it as a great idea, and the team discussed what needed to be done to implement it.

Reflexivity and learning.

- Because of different backgrounds, they [researchers] have different terms. Maybe you don't know the terms; any of the term that is not from your background you need to learn.
- So, how have you been dealing with this issue?

- I keep learning. After I take off from the lab in the evening I learn.

Junior Researcher

Reflexivity and learning was found to be another factor that influenced the work and progress of the examined teams. The importance of the factor was strongly supported with data obtained during interviews. In addition to the interview data, the role of *reflexivity and learning* factor became evident during my observations of how team members interacted with each other, while preparing for clinical trials, conducting the trials, and meeting after the trials to discuss results and next steps. Based on the data, it was apparent that reflexivity and learning in an interdisciplinary research team may take (at least) two complementary forms: (a) reflection and learning on how to function as a team while doing research, and (b) reflection and learning on research activity itself.

In one of the examined cases, one research team purposefully held two training sessions to learn how to work as a team and operate their (new) equipment in order to conduct trials with patients. The *reflexivity and learning* factor was evident in one of the training sessions that I attended. During the session, I observed how, on the spot, the team members were calling out actions that they were performing and shared (in a loud voice) the data they were reading from the tested equipment. In the meantime, one of the team members was taking notes (using the white board) on the critical issues that the researchers were experiencing. At the end of the session, the group summarized what needs to be considered and done before the next training session. During my observation of the team's (first) trial, it was evident that the researchers had successfully addressed the issues of their concern and were able to function as a team.

In another case, the *reflexivity and learning* factor was apparent during two meetings that took place after the team's trials; during which researchers were taking time to reflect on their experiences on site and discuss their takeaways from those experiences. Specifically, at the meetings, team members discussed what had been done during their trials, what difficulties (or surprises) team members encountered, and how all this information could inform their next steps. In one of the two meetings, a junior researcher commented on an issue that the researchers encountered during their data collection, which, according to the researcher, was not addressed in the relevant literature. The team discussed the issue in detail and considered a possibility to explore it further (as this issue was within the scope of their research problem). As discussed with the researcher two months later (personal communication), the team had collected additional data and submitted a research paper on the topic to a highly regarded conference within their field.

As demonstrated in the above cases, *reflexivity and learning* appeared to be an important factor that facilitated the work and progress of interdisciplinary research teams.

Balance in team members' expertise and input.

> We had a very good balance of people doing different roles to advance the project and presenting the project and things like that… The things we were good at in the project balanced each other and complemented each other. So, that was all really helpful.
>
> Junior Researcher

One of the factors influencing the work and progress of interdisciplinary research teams that was evident was the balance in team members' expertise and input.

Specifically, it was apparent that researchers' expertise was one of the criteria for labor division in the examined projects. When a project was "balanced" regarding expertise and input that team members were bringing to the projects, other team members appeared to be more cognizant and appreciative of other researchers' work. Balance in team members' expertise and input also appeared to be characterized by participative decision-making processes, which, in turn, led to the higher levels of engagement among researchers in the examined projects.

Researchers' expertise appeared to be one of the criteria for the division of labor in the examined projects. As one informant discussed, when there was a need for particular skills or knowledge in the project, and there was a team member with an appropriate skill-set on the team, the person would usually take over that aspect of research. At the same time, if "there wasn't anyone who was naturally more qualified for that aspect," team members typically "tried really hard to keep parity." As such, balance in expertise appeared to provide good grounds for the scholars' recognition of other researchers' contribution to the project; not only did the researchers felt they were contributing to the project goals, but they also valued other collaborators' contribution. As one of the informants observed: "What works really well is that Robert and I completely recognize our own strengths, and we recognize the strengths that the other has. So, it's really pretty equal on the project, I think, having a kind of equal saying, equal expertise." Similarly, researchers also appeared to be in favor of those research environments where project goals and major decisions were determined collaboratively, through the input of various experts and not just one leader:

> Many collaborative projects end up with kind of one person really driving it. And then it's kind of pulling in other people to fill in the gaps, but it's really one person kind of driving. And I've been with some of those but those are not as much fun for me, because you feel like you are just a part… a little cog that is being dragged along by the others. So those aren't that interesting to me. I much prefer the ones where, you know, it's equal weight in terms of project direction.

Analysis of interview data and field observations also suggests that "balanced" teams (with regard to team members' expertise and input) appeared to be characterized by participative decision-making processes (as researchers are more dependent on each other for making key decisions in "balanced" teams). Therefore, in "balanced" teams, researchers appeared to have high levels of engagement, which, in turn, facilitated the work and progress of their interdisciplinary research teams. The excerpt below supports this finding. In the excerpt, a junior researcher reflects on her transition from "stepping into" her role to getting "an equal" role in the research project, and how this transition was facilitated by her involvement in decision-making process.

> I'd say stepping into my own role has really helped a lot with progress. 'Cause once I realized… it wasn't until a couple of meetings… I was giving some opinions here and there, doing what I was told, and following the previous research manual, and then, after that Dr. [name] would ask me, like "What do you think would be better? What do you think?" … So, now I have just as equal role in this project. Usually, if there's anything on the technical side that I think could be better, it gets implemented. And I think it's great how I've been more

> confident speaking my opinions, and that Dr. [name] trusts my opinions, and wants my opinions. I think that's a big thing, 'cause I can give a lot to this project.

As the junior researcher noted above (and this finding is also supported by other data from this case), the junior researcher's appreciation of "just as equal role" on the project facilitated the work and progress of the research team.

Shared Purpose.

> Every member in this project has a common aim that is to discover a new drug. Everybody is working towards it. I think it inspired us to work very well in this project.
>
> Junior Researcher

As a result of data analysis, *shared purpose* became evident as another important factor pertinent to the focus of the inquiry. This factor was related to the *collective* aspect of formulating the purpose of research, which directed team's efforts throughout the project implementation. Data analysis revealed the following two characteristics of the factor that impacted the work and progress of interdisciplinary, university-based research teams: (a) the extent team members jointly contribute to the formulation of research purpose (i.e., researcher's contribution to the formulation of the purpose at the beginning of research), and (b) the alignment between the researchers' interest(s) and grant specifications as enabler for defining the purpose of research. As it became apparent in the examined cases, both characteristics had an influence on the work and progress of the examined teams.

Several researchers noted in their interviews that their research objectives were jointly defined as a result of their communication with (key) team members (and were not

imposed by someone, e.g., a leading researcher). Having more or less "equal weight in terms of project direction" appeared to be beneficial to the work and progress of research teams as, in this case, researchers saw themselves as "contributors" as opposed to contractors. The following excerpt from an interview with a senior researcher supports this finding:

> You can certainly gauge that if, let's say, it's a proposal-driven activity [vs. a person-driven activity]. You can certainly gauge that pretty well by looking at the ratio of words that each contributor writes in the proposal. And the more it's 50/50… and I think the more you've got it... if it turns out to be 90/10 then, you know, "OK, it's a different sort of deal."

While the study did not explore the interaction between the researchers at the problem formulation stage, it was apparent from my discussion with the informants that the more input into the *shared* purpose team members provided, the more engaged the researchers were in the process of their projects' implementation.

The formulation of research purpose in interdisciplinary research is challenging (during the pilot study some interviewees referred to the problem formulation as the most challenging aspect of conducting interdisciplinary research). As it became evident in one of the examined cases, grant specifications could provide a framework (and incentives) for researchers to have focused discussions around their ideas to formulate a purpose of their inquiry. As one of the team members observed,

> I think because there was a proposal and a call, and they had certain criteria they wanted to meet and things like that… that helped us focus on actually pretty something [the project], because… now it wasn't extra, it was for a purpose. I

think it helped us to have a purpose to actually complete it, because have this call never would come up, I don't know if we ever would have actually worked on it.

In other words, the alignment between team members' research interests and the grant criteria were found to facilitate the work and progress of the university-based teams in the following way: first, it enabled the team to formulate the (shared) purpose and, then, to stay focused on the purpose of their research throughout the project's implementation.

Organization-Level Factors

Two factors at the organization level of analysis also became evident as a result of data analysis. These factors were the following: (a) organizational structures and (b) organizational culture and environment.

Organizational structures.

> I do think something like the [XYZ] Center, which actively incorporates people from different departments, helps. It seems just like a lot of rhetoric, right, 'cause that's how it comes across, but… in order for people to form those informal connections you do need something that is a bit formal to catalyze it.
>
> Junior Researcher

During the interviews, various researchers pointed to the organizational structures as an important factor influencing the work and progress of interdisciplinary research teams. In some instances, organizational structures were recognized as enablers, in other instances, the existing structures were also seen as barriers. With regard to the "supportive" structures, the interviewed participants acknowledged the role of research centers and grant-funding institutions within the university in enabling collaboration among researchers from different disciplines. In particular, in two of the examined cases,

the university's Institute on the Environment and the Institute for Engineering and Medicine were recognized by the interviewees for providing various funding mechanisms for interdisciplinary research. In addition, the Institute for Advanced Studies was acknowledged for providing so-called seed grants that were aimed at bringing a group of researchers that had not worked together before together. Some of the interviewed researchers also noted the role of the Office of Technology Commercialization as an important enabler for transferring the team's innovation to the marketplace (as it was evident in one case).

While some existing structures were seen as supportive to the work and progress of interdisciplinary research teams, some structures also created challenges for collaboration across disciplines. For junior researchers, organizational structures (departments and colleges as organizational units) sometimes served as communication barriers that hampered the researchers' opportunities to reach out to faculty and students in other disciplines while seeking for advice and/or potential collaboration. As noted by one of the junior researchers:

> When the graduate school brings people together, we are brought together on this campus, with the people within this building. You know, like all of the social things [events]… So, if I'm going to interact with anybody that is not on our project, but I'm just interested in their work and want to learn something from them, I have to schedule a meeting. You know, it's very like, "Why are you here? What do you want?" I have to be really purposeful about it… I mean I feel really fortunate to have [names], they are great advisers, and they are the reasons why I'm here, but, otherwise, it feels like isolated within the department.

For senior researchers, these challenges were primarily related to logistical difficulties to work with somebody from a different department or college (especially if the unit was located at another campus of the university). An interesting finding was that a researcher from the College of Science and Engineering was housed in an office located in a different college, to be in closer proximity to the area of the scholar's research interests.

Organizational culture and environment.

> I think the enabling factor is the University itself, which has a culture whereby faculty are here to help each other. It's not all individual. So he [another researcher] is aware of that, I'm aware of that. The medical school fosters it. The engineering area fosters it. We all want to help the world get better and so the people across campus with engineering skill are gladly going to be able to help people on this side of the campus with medical skill. So, I think, it's a culture that is what I'm describing right now. We are all here to help each other.
>
> Senior Researcher

The majority of researchers interviewed in the study (both senior and junior) directly spoke about organizational culture and/or environment as an important factor that influenced the work and progress of their interdisciplinary teams. The following properties of the *organizational culture and environment* became evident as a result of data analysis: (a) interdisciplinary research recognition at the department level (i.e., for tenure and promotion), (b) faculty engagement with research and teaching across departments.

Several senior researchers (mainly from the engineering field) explicitly noted in their interviews that the fact that their interdisciplinary research was recognized at the

department level was a facilitating factor for the researchers to work on research problems that required interdisciplinary efforts. Two of the interviewed faculty mentioned that they had been hired because of their prior interdisciplinary work and the fact that their departments supported their approach towards interdisciplinary research was enabling for them. As one of the researchers observed,

> One thing that was enabling is that I'm in the department where… When I started working, I just got my faculty position… I am a tenure-track associate professor now… But, in the beginning, I knew I joined the department that would recognize contributions that I was making to that project, and that's enabling. It produced high impact results and my department recognized that.

In addition, as data analysis revealed, faculty engagement in research across various departments/colleges was a sign of the organizational environment that is supportive of interdisciplinary research. Specifically, faculty's research/advising across departments created additional research opportunities for students. For instance, in one of the examined cases, the interviewed students (belonging to two different departments) reported that the fact that they were co-advised by faculty from different research groups resulted in establishing "a low barrier" to forming their (student) research team. As one of the junior researchers observed:

> … big is having an environment in which people can collaborate…That already existed when we started this competition. But I think, you know, if the [name] group was really closed-off, didn't talk to the [second] group, to the [third] group, we wouldn't have ever done this. And the Center [name] is good for this, 'cause it promotes a cross-talk between faculty and students.

Several faculty members noted during the interviews that they were officially cross-appointed (and, as noted above, even housed) in other departments. The faculty also acknowledged that their appointments in other departments provided additional opportunities for interdisciplinary research.

Institution-Level Factors

Analysis of the interview data pointed to the presence of a number of factors that were shaped by institutional forces, i.e., the way things get done in academia in general. These forces were certain rules and conditions that influenced the work and progress of interdisciplinary research teams and, also, individual researchers working on the teams. Specifically, the following two factors became evident in this category: (a) scheduling and planning in academia and (b) traditional perspectives about what makes an independent scientist.

Scheduling and planning in academia.

> It's also interesting to think, to appreciate, how scheduling and planning differs between a university and a hospital, for example. So, like I said, this grant was executed and began in January. Our [company] partners said, "Great. Let's get started." And we had to say to them, "That would be great to get started, but because we have to have students to work on this, we don't… you know, our students rollout happens with the new academic year. So, in order to get them and power to do the project, we really are handicapped until September. We can admit students, but they won't get here until September. Unless we go and schedule for students right now that are already at the University and need funding, it's hard for us to start, right, when this grant began. And that was something that, again, to

> the [company] people semesters don't matter… They don't work in the world of academia. If the money comes in January, you start work in January. For us, trying to manage the project in the world of academia, these things matter.
>
> Senior Researcher

Scheduling and planning in academia refers to the fact that public research universities (including this university) function using particular (often semester-based) calendars. These calendars set certain time-frames for university research teams with regard to their own time-lines, e.g., when to apply for grants (or report on the results), or when to schedule a break (e.g., during a spring break). While most of the interviewed participants took the existing calendars for granted, scheduling and planning in academia was found to be an influential factor in one of the examined cases (see the excerpt above). Specifically, when the partner organization could have started the project already in January, the university researchers could fully engage in the research project only with the start of the academic year. Therefore, this factor caused a delay with the project inception.

Traditional perspectives about what makes an independent scientist

> Graduate students come to do PhDs… the old model is to have a really clean isolated project. They go off for three years to do that whole thing. I don't think that's very practical. It doesn't prepare people for the real world anyway.
>
> Senior Researcher

In this study, traditional perspectives about what makes an independent scientist mainly refers to the issue of performance assessment of faculty (and students) and, in

particular, how researcher's contribution is acknowledged in academia. As noted by one of senior researchers:

> In general, in science our structure for various reasons hasn't rewarded these collaborative projects. I mean, for me, it would be better for my career if I had three independent papers where I was the last author and the only senior author. It'd be better for my students, if they had three first-author papers, where they are the only first authors listed first. It could be better for them… It depends who will look at their CV. But, certainly, for some departments tenure and promotion, they sort of look at papers with that many authors and they say "What did you really do, 'cause you've got sixty authors on this paper?"

While authorship appeared to be a minor concern in the examined projects, some of the interviewed faculty acknowledged that authorship, in general, is a factor influencing interdisciplinary research; especially, if interdisciplinary research teams included a large number of contributors. As noted by some informants in the pilot study, different disciplines may have different criteria for authorship. The different criteria for authorship could present additional challenges at the stage of dissemination of research results, when a team had to decide how to acknowledge each researcher's contribution in a publication.

Project Management Aspects of Conducting Funded Research

Data analysis pointed to the presence of another group of factors influencing the work and progress of interdisciplinary research teams, broadly defined as *project management aspects of conducting funded research*. This group of factors differed from the aforementioned four groups, as it did not clearly correspond to the conventional typology of levels of analysis (i.e., individual-, team-, organizational-, and institutional-

levels). Yet, given the frequency with which issues related to this category were highlighted (e.g., participants often referred to their research activities as research projects in their interviews), as well as the importance of the factors given the data analysis, it made sense to report the group of factors as another finding. The following three factors were evident in this category: (a) funding, (b) staffing, and (c) previous and intermediate outputs. All the three factors were recognized by the participants as important for research teams to initiate and implement their research projects.

Funding.

> What's challenging with collaborations is you frequently have no money. So, you have this great idea, you have all these people, you have all this work you want to do, but have no grant. And to get a grant you need preliminary data. So, it's very cyclical. It's a terrible cycle…
>
> Senior Researcher

Two sub-themes emerged in the data analysis with regard to this factor: (a) funding as important condition to carry out interdisciplinary research projects, and (b) seed funding as a mechanism to start new research collaboration. The first sub-theme relates to the fact that research activities in a public research institution are contingent on available resources, including financial resources. As multiple interviewees noted, interdisciplinary research activities largely depend on available financial resources, typically acquired in the form of research grants that come from a limited number of funding sources. As financial resources are limited, research teams often need to compete for the scarce funding, e.g., by providing a justification (and some preliminary evidence) that their research is indeed worth to fund. With respect to interdisciplinary research (and,

especially, novel research, with only some (or no) preliminary evidence), obtaining funds for the university-based teams becomes challenging, as noted by a senior researcher in the aforementioned excerpt.

During the interviews, senior researchers from two teams noted that seed funds, issued through one of interdisciplinary centers at the University, provided opportunities for the researchers to invest time and efforts in formulating their research problems and, after obtaining some preliminary results, to apply for other (bigger) research grants. As discussed by one of the senior researchers:

> They're called seed grants… They're premised on an idea that you are bringing a new group together that did not work together before; you have a novel idea, you can prove that it will be competitive for external funding. They give you a significant chunk of money often to get things started and that's important, I think. That allows people to devote time to it, it brings people together. You might get a paper too, that's important, especially, for NIH. If you don't have productivity already, you're not going to get one of these big grants of NIH, you have to show. It can't just be an idea, with NIH, it has to be an idea that is already down the road; it's got progress, so they want to fund it. [University of …], I think, does a really good job at seeding those kinds of efforts.

While seed grants were recognized by the interviewees as an important mechanism to start collaboration on interdisciplinary research, one researcher also noted that the seed grants' specifications (with emphasis on new collaborations) sets certain limitations for the already established research teams: "And now, that we have a seed grant, we can't get another seed grant, because we don't count as a new collaboration. That's a kind of a

challenge." The researcher suggested that establishing another type of a grant, "seed grant 2.0," could help the newly formed teams that had already received the seed grant to sustain their research efforts.

Staffing.

> The collaboration was started by the PIs [names], but the people doing the work in the lab are not us, that's the people that we hire. So, it's actually largely depending upon the skills, the expertise, and the initiative of the people that we're hiring. They need to be very hard-working, they need to be dedicated, and they have to be at the same level of willingness to be true collaborators with each other. That's not enough that me and [another Co-Pi] get along. Our postdocs have to be able to really communicate and work together as well.
>
> Senior Researcher

During the interviews, senior researchers of the faculty-led research teams (in three cases) noted that they were paying particular attention to the selection of junior researchers to join their research projects. According to the researchers, having students (staff) with relevant technical expertise, motivation (interest in the research area), and experience in team research was a contributing factor to the work and progress of their research teams (see the excerpt above). This finding was consistent with data from the project documentations. For instance, a job posting for a postdoctoral student position in one of the projects specified the following requirement, in addition to some specific task-related skills: "excellent self-motivation and capacity to work as a member of a team (required)."

Several junior researchers also noted, when reflecting on how they joined the research teams, that their motivation, research interests, as well as prior work in research teams were the important characteristics that their supervisors were looking for. As one of the researchers recalled:

> [Professor] had an interview with me. She talked a little bit about [the project]; she mentioned that she had a project that needs some experimental techniques. I was very familiar with the techniques. Also, that [the project] needs collaboration skills because that is a transdisciplinary project.

The fact that senior researchers have taken efforts to select the "right" staff for their projects was also partially corroborated during my field observations. When visiting the labs, I observed that junior researchers spoke highly about their collaborators (junior researchers from other departments and/or colleges) as team players and commended on their contribution to the projects' outputs.

Previous and intermediate outputs.

> Well, we will have to give a progress report to the Fund, which is [name], and then tell them: "This is what has been accomplished, this is how your dollars were spent." And then they could make a judgment and say, "OK. Yes, you did a good job and we might fund you again." They give it to us on a hope that it will make a difference. But they don't take the money back, if it does not make a difference. It's gone. It's just the way it is for any of these grants. But it *does* influence whether you'll get more money in the future. If you have one success, it is more likely to lead to another funding source.
>
> Senior Researcher

As it became apparent in data analysis, in interdisciplinary team research, previous and intermediate outputs to the researchers' activity, and/or each of the engaged disciplines and practices, were an important aspect that promoted continuity of the team's activity. The role of the previous and intermediate outputs appeared to be three-fold. In the examined cases, these outputs (a) provided an opportunity to apply for another (larger) funding; (b) enlisted confidence in team members that the team was moving in the right direction in terms of obtaining the desired results; (c) provided insights into new and unexplored areas of research that the team members have not previously considered in their grant applications.

As found in several interviews, the interviewed participants typically had some specific expectations with regard to the desired outcomes of their research activities (usually specified in their grant applications). At the same time, (positive) intermediate outcomes often provided opportunities for the teams to acquire some additional funding, to sustain and scale up their research activities. For instance, in one of the examined cases, a team of researchers started their collaboration with a (small) seed grant that enabled the team to obtain some preliminary (promising) results. While still within the time-line specified in the seed grant, the team submitted an application for another (larger) grant, in which they outlined the work that has been done, results they have achieved, and their next steps. After winning the second (competitive) grant, the team had enough resources to hire a postdoc student to work in the project and set more ambitious research objectives.

As discussed with the members of another (student-led) team, after receiving an award for their research proposal (in a competition organized by a private entity) as well

as obtaining positive feedback from the executives and their advisers, the team members were quite enthusiastic to move forward, conduct more research, and file a patent. As one of the researchers observed:

> We ended up winning, our team. There was a lot of motivation to continue the project, before it was just an idea, and we got a lot of positive feedback from the executives of [company]. I think it was definitely another catalyst that helped us pursue it further, and we, actually, filed a patent, and made a publication.

Lastly, as it was evident during observations of another (third) team, after obtaining some (intermediate) results from their trials, the team decided to expand on their research activities and explore a related issue, which was still within the scope of their research problem. To answer their (new) research question, the team collected some additional data (i.e., had some more trials), analyzed the data, and submitted a manuscript to present at a prestigious conference. As discussed with one of the researchers, their results were promising to shed light on yet unexplored area of the practice that the team was studying.

Summary

This chapter discussed the key findings resulting from my data analysis that employed data collected from four cases. As noted at the beginning of the chapter, my analysis of the rich contextual data and the reviewed literature led to (a) answering the research question that guided the inquiry – *What are the factors that influence the work and progress of interdisciplinary, university-based research teams?*; and (b) formulating three theses characterizing interdisciplinary, university-based research teams as a distinct type of human system situated in a particular context. The three theses, together with the

model, are proposed to be the building blocks of the emerging, mid-range theory on interdisciplinary, university-based research teams.

Figure 2 provides a summary of the findings concerning the typology of the factors that influence the work and progress of interdisciplinary, university-based research teams. In particular, five major groups of factors became apparent as a result of the analysis. Four groups were to a large extent similar to those discussed in the literature on interdisciplinary research: *individual-level factors*, *team-level factors*, *organization-level factors*, and *institution-level factors*. One group – *project management aspects of managing funded projects* – was the category that has received only some attention in the literature.

In the following chapter, I will elaborate on the three theses and discuss directions for future research, study's practical implications as well as its limitations.

Chapter 5: Discussion

This study employed a multiple-case research design to explore factors influencing the work and progress of interdisciplinary, university-based research teams. Four cases (research teams) were examined using data from interviews, observations, and project documentation. Chapter 4 outlined key findings of the study and presented the model of key factors influencing the work and progress of interdisciplinary research teams. Chapter 5 starts with a brief overview of the study findings and also provides an overview of how I generalized the data in order to conceive the mid-range theory. Then I provide my discussion of the study's theoretical contribution, directions for future research, study's implications and limitations.

Overview of the Study Findings

As the study employed qualitative research methodology, the study findings present a contextually rich look at the factors that impact the work and progress of interdisciplinary research teams operating in the context of a public research university. While the interest in team science has been growing lately (Cooke & Hilton, 2015), there is little research that has utilized a qualitative approach to explore the work of interdisciplinary, university-based research teams. Therefore, the study findings contribute to the team science literature and also broaden our understanding on various factors influencing self-organized teams; in particular, interdisciplinary research teams in higher education institutions.

While some scholars highlighted the presence of various factors that may influence interdisciplinary research collaboration in general (e.g., Stokols, Misra, Moser, et al., 2008), this study's focus was on interdisciplinary, university-based research teams, as well as on the factors that influenced their work and progress. An analysis of data from the four cases examined in the study resulted in the identification of important factors that were conceived at different levels of analysis. Some of the factors were similar to the factors recognized in the literature (e.g., intrinsic motivation, organizational structures). Some of the identified factors have not been thoroughly discussed in the literature and just recently started receiving scholars' attention (e.g., *busyness*, as in Bammer, 2016). Some of the findings were logical, expected, and, easy to interpret (e.g., *funding*). Some were less expected and emerged after thorough analysis of various data sources (e.g., *prior assumptions about other members' knowledge and skills*). In turn, some of the factors that have received considerable attention in the team science literature (e.g.,

authorship) were only noted by participants as the factors that may influence interdisciplinary research collaboration; however, these factors were not pivotal to the work of the examined research teams. As a result, in my data analysis, such factors were sub-merged into larger themes.

Ideal Typologizing and Category Zooming

As discussed in Chapter 3, I employed a qualitative approach in the study design, which sets some limitations to the extent the study findings could be generalized to other contexts (e.g., the work of R&D teams in the industry). At the same time, the strength of the undertaken approach is in analytical generalization (Halkier, 2011). Analytical generalizing on the basis of qualitative data can be done in various ways and has its own benefits. In particular, in this study, I employed two ways of analytical generalization – *ideal typologizing* and *category zooming* – to build the mid-range theory (the three theses and the model). What follows is a brief overview of the two approaches and an explanation how each of them informed this study.

According to Halkier (2011), *ideal typologizing* is used to convey "something more comprehensive about the empirical patterns related centrally to the research question" (p. 792). Utilizing this approach, researchers typically condense "the coded data patterns into a relatively limited number of descriptions which one-sidedly underline particular characteristics at the expense of others" (p. 790). As the title suggests, the output of this generalizing is a typology.

While *ideal typologizing* aims at a wide-ranging covering of the empirical data material, often with considerable reduction of complexities, category zooming is a way of

generalizing that "goes into depth with the details and complexities in one single point of the study" (p. 792).

The so-called "single variable generalization" (Miles & Huberman, 1994, 173-177), which is typically used in the grounded theory method, is one of the ways of *category zooming*. At the same time, as Halkier (2011) notes, in multiple-case research, *category zooming*, as a way of generalizing, is not reducible to "a single variable generalization approach," in particular:

> There are also ways of doing comparative multi-case research that leans theoretically more toward critical realism and social constructivism and which implies the use of going into detail with single categories in a more context-sensitive fashion. (…) where single categories are placed in context and their nonessential character underlined (p. 792).

While analyzing my data, I employed both ways of generalizing. The use of *ideal typologizing* was primarily driven by the main research question that inquired about the key factors influencing the work and progress of interdisciplinary research teams. The model of key factors depicted in Figure 2 is the result of the *ideal typologizing* that I employed in the study. At the same time, as my own research was unfolding, the richness of qualitative data provided deep insights into the phenomenon of interdisciplinary research teams operating in the context of a public research university. These insights led to the second "layer" of generalizing, which focused on the category of "interdisciplinary, university-based research team" as a particular type of human activity conducted in a given context. In the sense, while, from the beginning, the study aimed at identifying key factors influencing the work and progress of these teams, the context-sensitive fashion of

the multiple-case research (Halkier, 2011) and the richness of data allowed "zooming in" into the phenomenon of the "interdisciplinary, university-based research team." Generalizing via *category zooming* has also led me to the formulation of the three theses that elucidate the phenomenon of interdisciplinary, university-based research team and provide a more nuanced description of these teams as distinct human systems functioning in a particular context. The three theses, together with the model, are the building blocks of the emerging (mid-range) theory on interdisciplinary, university-based research teams.

In the section that follows, I outline the theoretical contribution of the study, while linking the study findings to the extant literature that informed the theorizing of the proposed theses and the model. In the next section, given my findings, I set a number of propositions that can further advance the theorizing and confirm (or disconfirm) the theory. I continue then with making practical suggestions aimed at facilitating the work and progress of interdisciplinary research teams in the context of a public research university.

Contribution to Theory

The study employed a qualitative, multiple-case research design. When discussing the multiple-case research design, Stake (2006), observed that "qualitative understanding of cases requires experiencing the activity of the case as it occurs in its contexts and in its particular situation" (p. 2). To wit, this study examined the work of four interdisciplinary, university-based research teams. In the process of data collection, I conducted interviews, held field observations, and collected various project documents of the respective teams. Informed by various methodological guidelines on how to conduct qualitative data analysis, I analyzed my data and also performed both within- and between cases analyses.

The aforementioned steps provided me with rich qualitative data that informed my conceptualization of the framework (the model) and the proposed theses. According to Eisenhardt (1989a), building theories from case study research requires a "comparison of the emergent concepts, theory, or hypotheses with the extant literature. This involves asking what is this similar to, what does it contradict, and why. A key to this process is to consider a broad range of literature" (p. 544). While making analytical generalizing, I was consulting with the reviewed literatures and also identified several new sources that further strengthened the validity of my conclusions.

As a result of my analysis of the four cases, corroborated with the reviewed literature, I propose three theses and the model that set the foundation for the mid-range theory elucidating the phenomenon of interdisciplinary, university-based research teams and the typology of the factors that impact the teams' activities. In the sense, the presented below theorizing strives not as much for the grand ideas (as in a grand theory) but rather for the contextual specificity and utility of these ideas (Halkier, 2011). To further confirm (or disconfirm) the three theses, I also suggest several propositions that set directions for future empirical research.

First thesis. *Interdisciplinary, university-based research teams are open systems that adapt and evolve as new research opportunities and situational demands unfold.*

My analysis of the data collected from the four research teams (cases) suggests that interdisciplinary, university-based research teams are open systems that adapt and evolve given the arising research opportunities and challenges. Thus, the examined research teams were open to getting feedback and assistance from other researchers and practitioners, either on the temporary or permanent basis, when under constraints. For

instance, in the case of the development of chemically recyclable foams, the research team sought assistance from two undergraduate students who assisted with the lab work ("as synthesis of foams takes a lot of trials"). In another case, to conduct all necessary trials within the new, constrained time-line (when it became challenging to coordinate schedules among the team members), the team invited another physician to assist with the trials.

When a situation demanded (e.g., a set-back with the garment measurement), the examined research teams could make adjustments in their working schedules. At the same time, the larger, organization context set certain frameworks the teams had to deal with and adjust to (as in case with the garment team that had to postpone the implementation of their research until the start of the new academic year).

Depending on the quality of their results, the teams were motivated to continue and, often, scale up their research activities, by conducting more trials, translating their results into a conference paper or publication, and/or further developing their prototype(s) (where applicable). In addition, interdisciplinary, university-based research teams, depending on the specifics of their research designs and the stage of research, were open to considering various funding sources, both within and outside the university.

Lastly, the landscape of the teams' research activities often expanded the university boundaries. While two teams were using on-site facilities, one team was using a clinic in another city for its data collection. In another case, the second round of the team's trials was scheduled to take place over the Internet, with patients staying in their homes.

The discussion on teams as open and adaptable systems is in line with the emerging research in the fields of organizational studies and HRD that calls for viewing teams as open systems influenced by various contextual factors and capable to adapt and evolve given situational demands (Kozlowski & Ilgen, 2006). For instance, in the context of cultural-historical activity theory, Engeström (2008) suggested that teams should be analyzed as open and dynamic systems, and that researchers should pay attention to the object (motive) of the examined teams as well as various contextual factors pertinent to the human systems. While Kozlowski and Ilgen's (2006) and Engeström's (2008) conceptualization regarding teams and teamwork is broad and may characterize different teams functioning in various professional contexts, the proposed first thesis is "zooming in" into a particular type of teams, such as interdisciplinary, university-based research teams. Specifically, in light of the growing attention toward the science of team science (Cooke & Hilton, 2015), the first thesis suggests the utilization of a more complex, open-systems perspective to examine and facilitate the work of university-based, interdisciplinary research teams.

Second thesis. *The work and progress of interdisciplinary, university-based research teams is a function of multiple interacting factors situated at different levels of analysis (including individual, team, organization, and institutional levels).*

An inquiry into the factors influencing the work and progress of interdisciplinary research teams in the context of public research university was central to this study. As a result of data analysis, which included within- and between cases analysis and was substantiated by the reviewed literature, I proposed the model of the key factors that is depicted in Figure 2. As can be seen in Figure 2, these factors are situated at different

levels of analysis (i.e., individual, team, organization, and institutional levels). My examination of the data also suggests that, while some factors can be more influential than others, it is rather multiple factors at various levels of analysis, and not a single factor that impact the work and progress of interdisciplinary, university-based research teams. Therefore, the study findings suggest that the multilevel lens should be employed to understand functioning of interdisciplinary, university-based research teams.

As noted in Chapter 4, the model in Figure 2 presents a comprehensive view on the factors that may influence an interdisciplinary, university-based research team. However, given the fact that each research team is unique in its own way (as teams may vary in their research goals, the stage of research undertaking, or the time the researchers have spent working with each other), different research teams may be affected differently by (and also respond differently to) similar factors. To wit, the proposed model should be taken as a heuristic capturing the important factors influencing the work and progress of interdisciplinary, university-based research teams. At the same time, future studies exploring the effect of mediator- and moderator-type of variables (e.g., a group size) that may influence the relationships between the identified factors and the effectiveness of the research teams could advance our understanding on the work of interdisciplinary research teams in the context of public research universities.

Informed by the literature from the fields of organizational studies and HRD, I extend my discussion on this thesis in the following section, in which I suggest several propositions that focus on some particular factors identified in the study – connections and networks, team reflexivity, and balance in team members' expertise and input. The selection of the factors is based on my assessment of the literatures on R&D teams and

team creativity (e.g., Hoegl & Parboteeah, 2006; Mumford, Scott, Gaddis, & Strange, 2002), which provides good grounds to further examine these factors in the context of university-based research teams. Further exploration of the factors is promising to inform both the theory and practice of team science, with focus on university-based research teams.

In sum, the team science literature recognizes the presence of various contextual factors impacting interdisciplinary research. However, in their analysis, scholars either discussed factors influencing interdisciplinary research in general (e.g., Stokols, Misra, Moser, et al., 2008), or examined large research projects that typically involve multiple stakeholders and last several years (Stokols et al., 2010). The focus of the study is on small research teams that carry out their research projects in the context of a public research university. There is scant empirical research that has elucidated key factors influencing the work of interdisciplinary, university-based research teams. One of the study contributions is the identification of such factors (as depicted in Figure 2), which suggests that a multilevel lens is required to analyze interdisciplinary, university-based research teams.

Third thesis. *The work and progress of interdisciplinary, university-based research teams is contingent on diversity in expertise, social integration, and project management capacity of the teams.*

By definition, interdisciplinary research implies the integration of different information, tools, perspectives, concepts, and/or theories from several disciplines or bodies of specialized knowledge (NAS, 2004). This study investigated the research teams that were (a) composed from researchers from two or more disciplines, and (b) whose

research activities were transcending departmental structures (each team entailed researchers from different departments). The diversity in researchers' subject matter expertise, including their rigorous training and prior experiences in their respective disciplines, was an important criterion for the teams to be seen as interdisciplinary by their colleagues. The diversity of subject matter expertise that the researchers were bringing to their projects was the corner stone that enabled teams to reach the innovative solutions that would have been difficult (and, in many instances, impossible), if each researcher went it alone. The quote below, in which one of the informants reflects on her research team's composition, supports this idea:

> So, everybody has a piece of this puzzle. And it was just really obvious division of work and a division of expertise; which, I think, a lot of human health related sciences are really moving towards. I can't have expertise in all these different areas. So, I have things I'm good at, and I like to use the expertise of people who are really good at what they do.

The excerpt above illustrates one of the central ideas in the team science literature; it is the knowledge, skills, and experiences from different disciplines and bodies of knowledge that enables interdisciplinary research teams solve important social, economic, and health-related problems whose solutions lie beyond the scope of a single discipline (NAS, 2004). At the same time, supported by the study findings and also consistent with the growing literature, the following also became apparent: although diversity in expertise is key, by itself diversity in researchers' subject matter expertise was not sufficient for the teams to effectively pursue their research goals. In addition to diversity in expertise, the study findings underscored social integration and project

management capacity as additional components critical the work and progress of interdisciplinary, university-based research teams.

Interdisciplinary, university-based research teams are social systems. The study findings elucidated the important role of several factors that address the "social" aspect of interdisciplinary research, including *open communication*, *reflexivity and learning*, *balance in team members' expertise and input*, as well as *shared purpose* as pivotal to the work and progress of interdisciplinary, university-based research teams. When generalized at the higher level of abstraction, several sub-themes from the factors underscore the role of social integration in the work of interdisciplinary research teams. Social integration is defined as "the degree to which an individual is psychologically linked to others in a group," and it reflects "attraction to the group, satisfaction with other members of the group, and social interactions among the group members." (O'Reilly III, Caldwell, & Barnett 1989, p. 22). According to van der Vegt, Bunderson, and Kuipers (2010), social integration is key to effectiveness in self-managing teams [including interdisciplinary, university-based research teams], as self-management necessitates a high degree of team member engagement and requires investment in the team and its processes and goals.

As discussed in Chapter 4, the informants highlighted the importance of the following actions, which fall under the social integration theme, including: team members being attentive to other members' opinions, considerations, and feedback; recognition of other researchers' contribution to the project; participative decision-making processes; and involvement in the formulation of research goals. Given the study findings and the growing literature highlighting the role of social integration in self-

managing work teams (e.g., van der Vegt, Bunderson, & Kuipers, 2010), social integration is proposed to be another necessary component pivotal to the work and progress of interdisciplinary, university-based research teams.

During my interviews, I observed that informants often referred to their research activities as "projects," implying certain logic of actions in the pursuit of their research goals. While demonstrating some adaptability, the examined teams were also operating under certain frameworks, typically specified in their grant application documents. The research teams were functioning using established budgets, certain time-lines (e.g., when to run their trials and experiments), and had also outlined certain outputs with regard to what they want to achieve.

Managing of budgets, time-lines, and outputs required certain project management capacity on the side of team members, in particular on the side of senior researchers who performed the (co)-PIs roles. At the same time, project management capacity appeared to be not something that university researchers saw as their strongest asset, as noted by one of the senior researchers:

> Management of the complexity is difficult. You know, scientists are not the best managers… not the best managers, usually. That's not why we get into this field, because we are good managers, right. We are creative thinkers, and most people are pretty smart. We've got very little training about how to manage people and complex projects; we kind of figured it out on our own… We are all pretty resourceful, but you know, it's complex and timelines are… Yeah… it's hard I think to pull things together sometimes, when many of us don't have sort of the official training in that.

In this study, *project management aspects of conducting funded research* was identified as a distinct group of factors that shed light into the work and progress of interdisciplinary, university-based research teams. Specifically, three factors – funding, staffing, and previous and intermediate outputs – were identified as important factors falling under the theme. Corroborated with the literature that highlights the role of project management skills in the context of teams working on innovative projects (e.g., Hoegl & Parboteeah, 2006), this thesis underscores project management capacity as another important component integral to interdisciplinary, university-based research team performance.

Both social integration and project management skills are the constructs that have received attention in the management literatures, and have been explored in both theoretical studies and empirical research (e.g., Hoegl & Parboteeah, 2006; O'Reilly III, Caldwell, & Barnett, 1989; van der Vegt, Bunderson, & Kuipers, 2010). The role of social integration has also been underscored in the team science literature (Klein, 2005; Salazar, Lant, Fiore, & Salas, 2012), yet there is little empirical research exploring the construct in the context of interdisciplinary, university-based research teams. Scholars have long employed the project management framework to analyze the work of R&D teams (e.g., De Maio, Verganti, & Corso, 1994; Roberts & Fusfeld, 1981). The need to evaluate large research projects, involving multiple stakeholders, has also drawn scholars' attention toward the project management framework as a lens to inform the projects' evaluators (e.g., Stokols et al., 2010). At the same time, there is little understanding on how (small) interdisciplinary research teams carry out their research projects in the academic context, and whether there are differences between their project

work and research projects in other contexts. In sum, the third thesis, built on the study findings and corroborated with the extant literature on teamwork in various contexts, underscores that, together with diversity in subject matter expertise, social integration and project management capacity, are important constituents that enable the work of interdisciplinary, university-based research teams.

In sum, scholars in the management and HRD fields have done extensive research on teams in various professional contexts, and this research has informed our understanding on various aspects of teamwork as well as factors that influence team performance (e.g., Chatenier et al., 2009; Marks et al., 2001). For instance, team research suggests that a team size and diversity in team membership are important control variables influencing the relationship between various antecedents and team performance (e.g., Wheelan, 2009). In particular, a size of team is often seen as a double-edge sword: while a larger collective is expected to have greater functional expertise, larger groups also require greater amount of time for communication and coordination among its members (Wuchty et al., 2007). Likewise, in teams engaged in knowledge production, knowledge diversity typically "offers a broader base of information to be shared, but also offers conflicting and contradictory norms and assumptions regarding what might be considered optimal solutions or normal work practices" (Paletz & Schunn, 2010, p. 86).

Studies on research and development (R&D) teams further suggest that collectives engaged in collaborative knowledge production may differ from other teams as R&D often has a time-lagged and sporadic nature to its outputs (Narayanan, 2001). Research on R&D teams indicates that these teams typically have more educated and

creative employees (Berson & Linton, 2005), and managers in R&D teams have more experience in technical rather than managerial tasks (Elkins & Keller, 2003).

While research on teams and teamwork, including research on R&D teams, has been growing (e.g., Zheng, Khoury, & Grobmeier, 2010), there is scant empirical research that has examined interdisciplinary, team-based research in the academic context, with team membership not exceeding 10 members. The focus of this study was on interdisciplinary, university-based research teams and the factors that influence the teams' work and progress. One of the study contributions is the formulation of the three theses that, altogether, underscore some peculiarities of interdisciplinary, university-based research teams as distinct human systems operating in a specific context. The three theses and the model illustrating the factors influencing the work and progress of the teams make the building blocks of the proposed mid-range theory on interdisciplinary, university-based research teams. In the section that follows, I provide suggestions for future research that could further enhance our understanding on the work and progress of these teams, and also to verify the underlying tenets of the proposed mid-range theory.

Directions for Future Research

To further confirm (or disconfirm) the mid-range theory, including the three theses and the model, I propose several propositions that set directions for future empirical research. These propositions concern the work and progress of interdisciplinary research teams, and focus on the following three factors that became pertinent in the study: *connections and networks, team reflexivity,* and *balance in team members' expertise and input*. While the study findings provide options for a wide range of propositions, my selection of these three factors is purposeful. First, based on my

analysis, the selected factors appeared to be particularly influential and also evident across the majority of the examined cases. As noted in chapter 3, when selecting cases for this study, I sought to identify those (co)-PIs and research teams that were known for their interdisciplinary work, with the hope that lessons can be learned from the high-performing interdisciplinary research teams (as recognized by other researchers). The exploration of these propositions, therefore, promises to not only to confirm (or disconfirm) the mid-range theory but also to inform the practice of team science. Second, my review of the literature suggests that scholars have made some attempts to explore somewhat similar propositions in the management and HRD fields, e.g., in the studies that explored the work of R&D teams or creativity in teams (Hoegl & Parboteeah, 2006; Mumford et al., 2002). At the same time, to the best of my knowledge, there is scant empirical research that would explore these (or similar) propositions in the context of university-based, interdisciplinary research teams. There are opportunities to not only replicate the existing studies, but, being informed by the previous research, to take it a step further: while paying attention to the academic context, to ground research questions in more recent theoretical frameworks on teamwork (e.g., Kozlowski & Ilgen, 2006) and utilize recently developed tools for data analysis (e.g., network analysis).

Connections and networks. The first set of propositions address the *connections and networks* factor that became evident as an important factor in my data analysis. As noted in chapter four, in the majority of cases, core team members either had known each other or had collaborated on joint research projects before. As noted by some of the informants, their connections and networks facilitated the formation of their research teams. Among other things, they enabled the researchers to reach out to other potential

collaborators who possessed complementary expertise and/or resources, which were not available in their own research units. In addition, due to the already established ties between the researchers, the process of team formation also became more efficient. Therefore, I suggest that

Connections and networks that researchers bring to their research collaborations will facilitate the formation of interdisciplinary, university-based research as follows:

P1.1. Connections and networks that researchers bring to their research collaborations will lead to more diversity in team members' subject matter expertise and team members' affiliation.

P1.2. Connections and networks that researchers bring to their research collaborations will make the team formation process more efficient.

As the research projects were unfolding, researchers' connections and networks kept playing an important role in facilitating the work and progress of the examined research teams. As discussed in Chapter 4, one team used their connections to receive experts' opinion with regard to how to communicate their research ideas to a private entity. In two other cases, researchers used their networks to get temporary assistance with running experiments and trials, when the teams realized that they had limited capacity to keep up with their time-line due to other researchers' responsibilities (*busyness*). To wit, in times when the examined research teams required additional resources to address various challenges that the teams were facing and/or to scale up research activities (e.g., via new grants), connections and networks appeared to be an important factor facilitating their research activities. Therefore, I propose that

Connections and networks that researchers bring to their interdisciplinary, university-based research teams will enable their already formed teams as follows:

P 2.1. Connections and networks that researchers bring to their interdisciplinary, university-based research teams will enable the teams to respond to new research opportunities (e.g., calls for grants) more efficiently than those teams where researchers do not have developed connections and networks.

P 2.2. Connections and networks that researchers bring to their interdisciplinary, university-based research teams will enable the teams to obtain additional resources (including ideas, human resources, or funds) in more efficient and effective ways than those teams where researchers do not have developed connections and networks.

Connections and networks has been recognized as an important antecedent to innovation, creativity, and performance in various studies that employed the social capital and social competence frameworks (e.g., Chen, Chang, & Hung, 2008; Lans, Verhees, & Verstegen, 2016). For instance, using data collected from teams of MBA students, Han, Han, and Brass (2014) found that team-bridging social capital, which the authors defined as "the resources embedded in a team's external network structure, characterized by a wide range of connections across diverse boundaries and rich in global structural holes" was an important variable contributing to higher team creativity (p. 55). These and other similar studies provide good grounds to further advance our understanding of the role of connections and networks in the context of interdisciplinary, university-based research teams.

Team reflexivity. My other proposition relates to the *reflexivity and learning* factor, and, specifically, to the team reflexivity aspect of it. Team reflexivity is defined as

the "extent to which group members overtly reflect upon the group's objectives, strategies and processes, and adapt them to current or anticipated endogenous or environmental circumstances" (West, 1996, p. 559). Team reflexivity is an important predictor to various organizational outcomes, including team performance (Schippers, Den Hartog, Koopman, & van Knippenberg, 2008, p. 1593). Team reflexivity was found to be positively related to social skills and project management skills (Hoegl & Parboteeah, 2006). Recent empirical research has also demonstrated that, when facing a demanding work environment, highly reflexive teams appear to be more innovative than teams that are low in reflexivity (Schippers, West, & Dawson, 2015).

In the present study, which focused on university-based research teams, reflexivity and learning appeared to be an important factor facilitating the work and progress of the examined teams. In addition, my data suggested that team reflexivity in research teams might take on different forms. In one case that I observed, researchers were holding a training session before conducting their trials, and took time to reflect on how they functioned as a team (as the researchers' actions required coordination and understanding what other researchers were doing at that time). In another case, I observed how researchers reflected on their preliminary data received in one of their trials and how the data were collected. In both cases, suggestions that the researchers were making based on their reflections furthered both teams in the pursuit of their research objectives. Given the positive effect of team reflexivity on the work and progress of the examined research teams, and also recent empirical research on team reflexivity, I propose that

P.3. Interdisciplinary, university-based research teams that are highly reflexive teams will demonstrate higher team performance than research teams that are low in reflexivity.

While scholars in organizational studies underscored different types of reflection and examined various factors affecting team reflexivity (Argyris, 1992; Schippers, Den Hartog, & Koopman, 2007), there is little knowledge on team reflexivity in university-based, interdisciplinary research teams and what organizational variables may affect it. For instance, transformational leadership was found to be an importance predictor to team reflexivity (Schippers, Den Hartog, Koopman, & van Knippenberg, 2008). At the same time, the social influence (one of the definitions of leadership) that I observed in the examined research teams could also be characterized as "distributed" or "shared." Therefore, in addition to examining the impact of team reflexivity on the performance of university-based research teams, future research could also explore the extent to which different types of leadership (e.g., distributed leadership vs. transformational leadership) impact team reflexivity in university-based research teams at different stages of carrying out their research projects.

Balance in team members' expertise and input. The next set of propositions refers to the *balance in team members' expertise and input* factor. As discussed in the previous chapter, one of the study findings was that, when research teams were "balanced" regarding expertise and input that team members were brining to the projects, team members appeared to be more appreciative of other researchers' work. As a result of my data analysis, it was also evident that balance in team members' expertise and input appeared to be characterized by more participative decision-making processes, and

also led to the higher levels of engagement among researchers in the examined projects. Recent research that examined the role of subgroups in teams also suggests that teams perform better when knowledge-based subgroups (i.e., formed according to information processing) are of equal size (i.e., balanced teams) (Carton & Cummings, 2013). Given the findings of this study and the results of recent research, I propose that:

P.4.1. Interdisciplinary, university-based research teams where team members' expertise and input are balanced (i.e., balanced teams) will be characterized by higher levels of participative decision-making processes than those teams where there is a dominance of one discipline

P.4.2. Interdisciplinary, university-based research teams where team members' expertise and input is balanced (i.e., equal sizes of disciplinary sub-groups) will be characterized by higher levels of engagement among researchers than those teams where there is a dominance of one discipline.

Studies in the fields of management and HRD have long underscored the important role of participative decision-making on various outcome variables, including job satisfaction, creativity, and employee performance (e.g., Lam, Chen, & Schaubroeck, 2002; Mumford et al., 2002). More recent research on employee engagement also underlines the role of engagement in the relationships between various predictors and a number of important outcome variables, including turnover intention, job performance, and organizational citizenship behavior (e.g., Rana, Ardichvili, & Tkachenko, 2014). Given the existing research supporting the role of participative decision-making and employee engagement in various organizational contexts, corroborated with the study findings, I propose that

5.1. In interdisciplinary, university-based research teams, higher levels of participative decision-making will lead to higher team productivity.

5.2. In interdisciplinary, university-based research teams, higher levels of researchers' engagement will lead to higher team productivity.

This section outlined a set of propositions that set directions for future research, with focus on interdisciplinary, university-based research teams. The following section discusses the study's practical implications.

Implications

This qualitative study explored four interdisciplinary research teams working in the context of a public research university. The selection of the cases was purposeful and entailed certain criteria, including the diversity in team members' field expertise and affiliations (the presence of researchers from different departments), heterogeneity in teams' support structures, and also in the areas of research and practice that the teams were addressing in their research. In addition, I aimed to select the teams whose research activities were within the so-called interdisciplinary-transdisciplinary continuum. My research design led to collecting rich contextual data, the analysis of which resulted in the formulation of the mid-range theory shedding light on the phenomenon of interdisciplinary, university-based research teams. The building blocks of the mid-range theory are three theses, the typology of the factors that impact the teams' activities, and also a number of propositions that can be employed to further confirm or disconfirm the theory. Building on the study findings, in this section, I discuss some practical implications of the study. Specifically, in this section, I outline practical implications for (a) researchers working in interdisciplinary research teams; (b) human resource

development (HRD) professionals who provide training and development opportunities to researchers, interdisciplinary research teams, and research organizations; and (c) administrators of research institutions.

Implications for researchers. As discussed in Chapter 3, to select my cases, I asked various researchers and administrators at the University, to recommend those (co) principal investigators, who were known for their cross-disciplinary research. As a result, while conducting the study, I first interviewed those researchers who were referred to me as good candidates, and, afterwards, when the four cases were identified, I also interviewed researchers from the examined cases. Together with the interview data that I obtained in my pilot study, all these interviews provided me with rich insights that can be summarized in a number of recommendations for researchers. While I interviewed both junior and senior researchers, these recommendations are primarily for senior researchers, although junior researchers may also find them relevant.

These recommendations concern: (a) the role of social intelligence and emotional intelligence in interdisciplinary research; (b) the value of using multiple lenses when managing research teams; and (c) the importance of social integration.

Social intelligence and emotional intelligence. The first recommendation relates to the fact that interdisciplinary team research is inherently a social activity, which involves the interaction between various participants in the process of research undertaking, including but not limited to other team members. While the development of cognitive intelligence is often the main focus in the traditional academic training, the study findings underscore the important role of social intelligence (such as interpersonal abilities) and emotional intelligence (such as intrapersonal abilities) in research

undertaking (Boyatzis & Saatcioglu, 2008; Zeidner, Matthews, & Roberts, 2004). Therefore, it is recommended for researchers involved in interdisciplinary research to invest time and efforts in developing their social intelligence and emotional intelligence competences. By doing this, researchers would not only enhance their capacity in understanding and managing their own emotions, motives, and behaviors, but also the emotions, motives, and behaviors other stakeholders involved in their research projects.

In particular, it is recommended that researchers consider various opportunities to develop their social intelligence and emotional intelligence competences. In addition to taking various self-assessment tests and attending relevant workshops (provided at their research institutions and by external vendors), researchers, and junior researchers in particular, should seek feedback and advice on their inter- and intrapersonal abilities related to interdisciplinary research from more experienced researchers (those who demonstrate a high level of competence). As noted in the following sub-sections, creating mentor programs that would pair more experienced and less experienced researchers could further facilitate the researchers' development in this and other components related to interdisciplinary research.

Multiple lenses for managing interdisciplinary research teams. As discussed in Chapter 2, managing interdisciplinary research is a challenging endeavor due to the inherent complexity of such research undertaking, as it requires the integration of knowledge, methods, tools, and expertise across two or more disciplines and areas of practice. As the study findings suggest, in addition to the complexity of knowledge integration, various factors, at different levels of analysis (including individual, team, organization, and institutional levels) may impact the work and progress of

interdisciplinary research team. Taking into consideration the study findings, it is recommended for senior researchers to use the multiple lenses when managing interdisciplinary team research, with attention being paid to different levels.

For instance, at the individual level, the study identified a number of motivators, such as (a) practical importance of work; (b) learning opportunities; and (c) career opportunities (primarily for junior researchers) that were important for the informants and warranted an investment of their time and effort in the respective research projects. The study findings suggest that senior researchers should consider framing the vision and direction of research in a way that it ties to some concrete (practical) implications. Similarly, in their work with junior researchers, senior researchers should take time to underscore the learning opportunities in research projects and, whereas applicable, to tie them to possible career opportunities. In sum, paying attention to the identified motives, senior researchers may not only recruit highly-motivated researchers, but also be able to sustain the researchers' motivation throughout the projects' duration, which, as noted in Chapter 2, may take more than one or two years.

At the team level, several other factors have been also identified as key to the work and progress of interdisciplinary research teams (see Figure 2). The use of the team-level lens, in turn, provides researchers with an opportunity to shift their focus from the individual level factors (e.g., researchers' motivation) and spot another set of factors that may impact the work and progress of their respective teams. As can be seen in Figure 2, the team-level factors underscored some social processes that may enhance research team's dynamics in various ways. For instance, the study underscored the role of team reflexivity and learning as one of the facilitating factors. In particular, consistent with

research in other contexts, I observed that interdisciplinary, university-based research teams that demonstrated high reflexivity appeared to be effective in reaching their (intermediate) goals. Therefore, it is recommended to use the team-level lens to foster a number of team processes that the study identified, including enhancing open communication and team reflexivity in research teams, to support them in the pursuit of their research goals.

In the examined teams, researchers had little influence over the factors situated at the organization and institution levels. Nevertheless, both organization and institution lenses are useful for researchers to recognize the larger contextual environments that may differ depending on particular organizational units, university, or national contexts. Specifically, as the study findings indicate, the larger contextual factors may set certain frameworks for the work of interdisciplinary research teams (e.g., when to start the implementation of research projects).

Social integration. As discussed in the chapter, the study findings underscore the role of social integration as an important component enabling researchers from different disciplines and areas of expertise to pursuit their shared research objectives. In interdisciplinary, university-based research teams, which are typically composed of both senior and junior researchers and where junior researchers often look up to their senior colleagues for feedback and advice, senior researchers should play a key role in fostering social integration in research teams. As it became apparent in the study, informants spoke highly of the research environments where (a) team members were attentive to other members' opinions, considerations, and feedback; (b) recognized other researchers' contribution to the project (including the formulation of the shared purpose), and (c)

those research environments that were characterized by participative decision-making processes. As interdisciplinary, university-based research teams are typically self-managing teams (as was evident in the four cases), high engagement of team members in bottom-up processes of coordination and self-organization is central for their performance (van der Vegt, Bunderson, & Kuipers, 2010). I suggest that by fostering social integration in their teams, senior researchers will create research environments that are characterized by high engagement, creativity, and innovation on the side of their team members and other contributors.

To summarize this sub-section: while previous research underscored that the intensity of interaction with group leaders was positively associated with creativity, particularly, for more junior scientists (Pelz, 1963), the study findings suggest that it is not just the intensity but also the quality of the interaction that matters in the context of interdisciplinary, university-based team research. In the sense, the quality of interaction can be enhanced through the above-stated recommendations. Specifically, it is recommended for senior researchers to consider developing their social and emotional intelligence competences, to use multiple lenses in managing research teams, and to foster social integration while conducting interdisciplinary research in the academic context.

Implications for HRD professionals

My interviews with researchers engaged in interdisciplinary research and administrators who are responsible for interdisciplinary research activities on campus provided good insights that can be summarized as recommendations for HRD professionals. In particular, in several interviews, researchers reflected on their training

(or absence of such) with regard to interdisciplinary research and also underscored several learning opportunities that were rather informal. With regard to training and development opportunities for interdisciplinary research, HRD professionals may consider the following recommendations:

1) Creating mentor programs pairing more experienced and less experienced researchers with focus on interdisciplinary research.

Given my interactions with informants, it became apparent that there are different mentorship programs in various units of the university. At the same time, only one of the interviewed researchers underscored the role of her mentor in enhancing her skills for interdisciplinary research. In particular, the mentor provided advice on how to develop an agenda for a research meeting to encourage participation of various participants. While there are already established mentorship programs in the university units, accentuating the interdisciplinary research component in the mentorship programs (and also establishing new programs focusing on this component) would facilitate the development of interdisciplinary research skills among junior researchers.

2) Linking the training content closer with the research context.

In my interviews, it became apparent that, on average, researchers had little exposure to formal training that would enhance their individual skills in conducting interdisciplinary research or facilitate the work of their research teams. Also, for those researchers who had received some training at the university (via a two-day workshop), they reported a great disconnect between the workshop activities and their actual activities and, as a result, expressed some dissatisfaction with the training. Given this information, it seems quite important for HRD professionals to consider linking the

training content as close as possible to a particular research context. While what seems to be an obvious recommendation – learning about the research context in the needs assessment – holds true, there are still some limitations as the interdisciplinary research context is quite specific and full of professional jargon (which is often unclear to researchers from other disciplines). Given my discussions on "what worked" in the trainings that some of the informants attended, the following two recommendations can be made for HRD professionals who are requested to design a training session:

2.1. Asking the participants to bring a case describing an actual problem that the participants are confronting (or confronted in the past), and to share with other participants their ideas on how resolve the problem (or how they did it in the past).

2.2. Involving an experienced researcher in the development of a case that would address some particular issues situated in the research context, so the participants could directly relate to the issues. In this case, the researcher may co-lead the case session and respond to some of the "context" specific questions.

The training activities discussed in 2.1. and 2.2. aim to link the training content closer with actual research contexts; therefore, making the designed training more relevant for its participants.

3) Using systems thinking in organizational development (OD) efforts aimed at fostering interdisciplinary research.

My third recommendation draws directly from the study finding that underscores the necessity to employ multiple lenses to explore and facilitate the work of interdisciplinary research teams in the context of a public research university. From the practice stand point, this means that HRD professionals assisting either an individual

researcher, or an interdisciplinary research team, or university administration on how to enhance interdisciplinary research on campus should, informed by their needs analysis, target change at several human systems and not just one: individual(s), team(s), organizational unit(s), and organization(s), or even at the institutional level, if applicable. While the applications of systems thinking and theory are not new to the field of HRD (Tkachenko & Ardichvili, 2016), due to the lack of empirical research that would have employed systems thinking and theory in the study of interdisciplinary, university-based research teams, the model depicted in Figure 2 may serve as a starting point in developing tools and models for understanding teams as complex systems, and providing specific recommendations for guiding OD efforts facilitated by HRD professionals.

In sum, when providing assistance with fostering interdisciplinary research, it is recommended for HRD professionals to utilize both formal and informal training and development opportunities in their work. It is recommended: (a) to consider launching mentor programs that would pair more experienced and less experienced researchers; (b) to link the training content closer with actual research contexts; and (c) to utilize systems thinking and theory in OD efforts aimed at fostering interdisciplinary research.

Implications for administrators of research institutions

My recommendations for university administrators are primarily based on my interviews with researchers and the reviewed literature. At the same time, the two formal interviews that I held with senior administrators in my pilot study do not contradict and, in fact, are in line with the stated below recommendations:

Research leadership. Braun, Peus, Frey, and Knipfer (2016) have recently suggested distinguishing between leadership of universities (i.e., *administrative*

leadership) and leadership in universities (i.e., *research leadership*). While the construct is very new and needs to be corroborated by empirical studies, some of the study findings support the idea that higher-level leaders (department chairs, deans) may indeed display particular behaviors that are conducive to fostering research, and interdisciplinary research in particular. Based on the findings and the reviewed literature, I would like to make the following recommendations for administration:

1) Creating an organizational climate for interdisciplinary research.

As discussed in Chapter 4, one of the study findings revealed the important role of the department chairs in providing contextual support in the form of a helpful organizational climate. Specifically, several (recently joined) faculty members interviewed in the study acknowledged the recognition from their department of their interdisciplinary research as "enabling." In addition to informal recognition, researcher's engagement in interdisciplinary research should be one of criteria for tenure and promotion.

2) Supporting and establishing organizational structures for interdisciplinary research.

During the interviews, various informants acknowledged organizational structures as an important factor facilitating the work and progress of interdisciplinary research teams. Specifically, the informants noted the role of interdisciplinary research centers and grant-funding institutions within the university. In the examined cases, two teams received funds through the initiatives of the university's Institute on the Environment and the Institute for Engineering and Medicine. Another team acquired some seed funds through the Institute for Advanced Studies. In addition, one team worked with the Office

of Technology Commercialization to transfer the team's innovation to the marketplace. While all the funds had been received through different grant application processes (often quite competitive), it is the existing organizational structures that enabled the teams to work on their research. Therefore, it is recommended to provide support to the already established institutions and create new structures that would support interdisciplinary research collaboration through various initiatives; targeting both newly formed interdisciplinary collaboratives and already formed research teams.

3) Creating opportunities for funding interdisciplinary research.

Almost all informants admitted that funding was key to the work and progress of the interdisciplinary, university-based research teams. When analyzed across the four cases, it was apparent that funds came from different sources. In some instances, university's funding sources allocated resources specifically for interdisciplinary research. In some cases, funding sources mandated research projects to be between particular university's institutions (as in one of the examined cases), or between the university and another partnering organization (e.g., as was evident in another case). In addition, funding that interdisciplinary research teams received through grants often paid for graduate students and post-doc scholars working in these teams. Therefore, it is recommended to increase opportunities for funding interdisciplinary research, both through the university units and also through various partnerships between the university and other for-profit organizations.

4) Increasing opportunities for the development of knowledge and skills for interdisciplinary research.

With regard to the development of knowledge and skills for interdisciplinary research, administrators of research institutions could consider the following:

4.1. Provision of training and development opportunities using various forms, including: formal classes (in various formats: face-to-face, online, or mixed), workshops and seminars, and also individual consultations. In addition to the above-mentioned forms, training and development opportunities targeting particular interdisciplinary research teams, based on their needs assessment, could be also considered. In this case, an experienced consultant would work with a particular research team given the results of the needs assessment.

4.2. Training and development opportunities that aim to develop social intelligence and emotional intelligence competences. As noted above, developing competences in these areas would enhance researchers' "soft skills," and the researchers will better understand and manage their own (and other stakeholders') emotions, motives, and behaviors.

4.3. Training and development opportunities that aim to develop project management skills. As the study findings and the reviewed literature suggest, interdisciplinary research teams are increasingly relying on the project management (PM) framework to carry out their research. Therefore, training and development with focus on the science and practice of PM would also enable researchers to design and implement their research projects more effectively.

In sum, given my interviews with researchers and the reviewed literature, administrators of research institutions could consider the following recommendations to facilitate the work of interdisciplinary research teams: (a) creating an organizational

climate for interdisciplinary research; (b) supporting and establishing organizational structures for interdisciplinary research; (c) creating opportunities for funding interdisciplinary research; and (d) increasing opportunities for the development of knowledge and skills for interdisciplinary research.

This section outlined the study's practical implications derived from the study findings and the extent literature review. What follows is my discussion of the study's limitations.

Limitations

As discussed in Chapter 3, the study utilized a qualitative research design. While the study findings present a contextual rich look on interdisciplinary, university-based research teams and the factors that impact the teams' work and progress, the generalization of the study findings to other professional and national contexts is somewhat limited. For instance, as some of the informants noted, and also consistent with other research, interdisciplinary research in the academic setting can be contingent on university tenure policies, often demanding from junior faculty (researchers) a clear "research identity" in order to get tenure and funding for their research. In addition, the way (and the extent to) which tenure policies may influence interdisciplinary research in different countries may differ. For instance, the European tenure system (and Ph.D. training in general) is quite different from the U.S. and Canada. In sum, as I collected my data in the university setting, the generalization of the study findings to other professional contexts (i.e., the industry) is limited. The extrapolation of the study findings to universities outside of the U.S. context should be also taken with caution.

In addition, the study examined four interdisciplinary research teams that are already established teams, with already secured funds for their research projects. At the same time, my interviews with researchers engaged in interdisciplinary research (including those conducted during the selection of cases) suggest that a collective of researchers may act differently if it already has funds compared to a situation when it is seeking money to fund the research. Hence, the study findings – the proposed mid-range theory, including the theses and the model – may not be fully applicable to analyzing the work of those collectives that have not formed as teams yet (i.e., are just beginning to formulate their research problem and define who will participate in the research). At the same time, gaining a more penetrating look at the research collectives and exploring the differences in the factors that influence the collectives and the established teams could provide additional insights and further inform the emerging theory on interdisciplinary, university-based research teams.

Conclusion

The study employed a qualitative approach, a multiple-case research design, to explore the work and progress of interdisciplinary, university-based research teams. My interest in this investigation sprang from my experiences as a researcher and also as a recorder at the *Grand Challenges* research forums at the University. My initial objective was to investigate the key factors influencing the work and progress of interdisciplinary research teams in the context of public research university. At the same time, in the process of conducting the inquiry, which focused on studying the work of four research teams, I gained deep insights into interdisciplinary, university-based research teams as a distinct form of human systems, which are situated in a particular context. My analysis of

the collected data, strengthened by the literature review, led to the formulation of the mid-range theory on interdisciplinary, university-based research teams. The mid-range theory entails three theses and the model of key factors influencing the work and progress of these teams.

As interdisciplinary, team-based research is gaining attention on the side of researchers, university administrators, and government agencies, the study findings will advance both the science and practice of "team science." In particular, the study sets a number of propositions, presented in Chapter 5, to further confirm (or disconfirm) the proposed mid-range theory as well as outlines practical recommendations for researchers, HRD professionals, and university administrators.

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Appendix A.

Table 1

Defining characteristics in typologies on interdisciplinary research

Multidisciplinarity	Interdiscipinarity	Transdisciplinarity
• juxtaposing	• intergrating	• transcending
• sequencing	• interacting	• transgressing
• coordinating	• linking	• transforming
	• focusing	
	• blending	

Source: Klein, 2010.

Appendix B.

Table 2

Summary of the four cases

Project	Team Size	Research Focus	Project Site(s)	Funding Source(s)	Espoused Timeline
Team A	4 (1)*	Stroke rehabilitation	University & Households	Internal	12 months
Team B	8**	Smart fabric	University & Clinic	Mixed	2x12 months
Team C	4 (5)	Recyclable foams	University	Mixed	14 months
Team D	5	Antifungal medication	University	Internal	12-48 months***

* The first number shows the size of the original team; the number in parenthesis shows how many additional people contributed to the project at later stages.

** Four researchers from the University and four staff members from the clinic have been on the team since the implementation stage.

*** This team received an internal grant sufficient to conduct research during the first year. The team was planning to acquire additional funds (via external grants) to carry out a four-year project.

Appendix C.

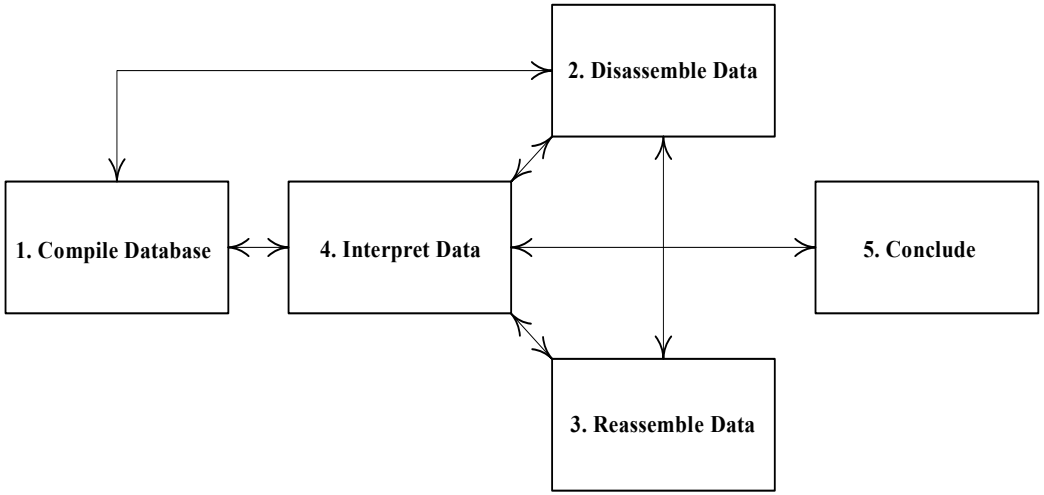

Figure 1. *Five phases of analysis and their interactions* (adapted from Yin, 2016).

Appendix D.

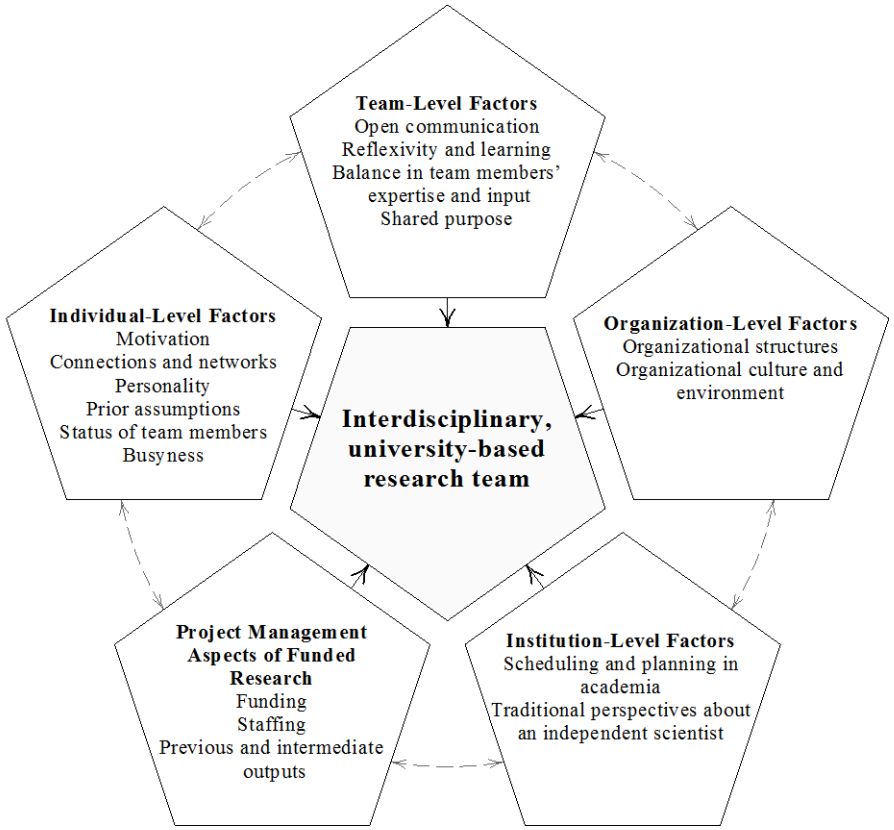

Figure 2. *Key factors influencing the work and progress of interdisciplinary, university-based research teams.*

Appendix E.

Letter to Identify Cross-Disciplinary Teams

Dear <**name**>,

My name is Oleksandr (Alex) Tkachenko. I am a PhD Candidate in Organizational Leadership, Policy, and Development, University of Minnesota.

I am writing to you to inquire about faculty and researchers at <**college**>, who are working on cross-disciplinary research project(s) where science and/or engineering is an important component.

I am working on my dissertation that explores factors influencing the work and progress of transdisciplinary (TD) research teams. The study addresses a recognized need for the investigation of resources and infrastructure within and across institutions to promote team science, as well as processes and methods that would encourage and support TD research teams.

At this stage, I am identifying prospective candidates for my study, to invite them for a first round of semi-structured (45-min) interviews. The aim is to learn about their cross-disciplinary teams' experiences in carrying out their research and select a smaller pool of teams for a subsequent, in-depth study.

My research is being supervised by Dr. Alexandre Ardichvili, Professor, Human Resources Development.

For your convenience, I am attaching my Information Sheet for Research/Consent Form that provides more information about my study.

Please do not hesitate to get in touch, if you have any other questions about my study. If necessary, I would be happy to stop by your office and tell you more about my research, if that would help you know who to recommend.

Thank you very much for your consideration!

Oleksandr (Alex) Tkachenko

Appendix F.

Participant Invitation Letter

Dear <**name**>,

My name is Oleksandr (Alex) Tkachenko. I am a PhD Candidate in Organizational Leadership, Policy, and Development, University of Minnesota.

I would like to invite you to be a participant in my dissertation research that explores factors influencing the work and progress of transdisciplinary research teams.

I am requesting your participation in a 45-minute interview, as you were referred to by <**name**>, as a very good candidate for this inquiry.

At this stage, I am conducting a first round of semi-structured 45-min interviews with PIs and RAs of cross-disciplinary research teams where science and/or engineering is an important component. The aim is to learn about cross-disciplinary teams' experiences in carrying out their research and select a smaller pool of teams (three-four teams) for a subsequent, in-depth study. Your subsequent participation in the project is voluntary, i.e., [if selected] you can decline the opportunity.

My research is being supervised by Dr. Alexandre Ardichvili, Professor, Human Resources Development.

For your convenience, I am attaching my Information Sheet for Research/Consent Form that provides more information about my research.

I understand that you may be extremely busy at this time of the year. I will do my best to schedule your interview at your convenient time within the next three-four weeks.

Please do not hesitate to get in touch, if you have any other questions about my study.

Thank you very much for your consideration,

Oleksandr (Alex) Tkachenko

Appendix G.

Information Sheet for Research/Consent Form

You are invited to participate in a research study that explores factors influencing the work and progress of transdisciplinary research teams. I would like to ask that you read this form and ask any questions you may have before agreeing to participate in the study.

This study is being conducted by: *Oleksandr Tkachenko, PhD Candidate in Organizational Leadership, Policy, and Development*.

Purpose of this study is:

to explore factors influencing the work and progress of transdisciplinary (TD) research teams. This research addresses a recognized need for the investigation of resources and infrastructure within and across institutions to promote team science, as well as processes and methods that would encourage and support TD research teams. Findings will inform higher education institutions and other relevant stakeholders about the conditions that facilitate the work of TD research teams and will further theoretical understanding on the interactions between self-organizing teams and their organizational /institutional environments.

Procedures:

If you agree to be in this study, I would ask you to do the following:

1) to participate in a semi-structured interview. During the interview, you will be asked to describe your team's experiences in carrying out your research. I will be recording the interview in order to transcribe the conversation at a later date. The interview will take no longer than 45-60 min. In particular, the following issues will be addressed:

(a) your research team's objective(s);
(b) your and other team members' field expertise;
(c) support structure and time-frame of your research;
(d) how your team emerged and has developed since then;
(e) how things get done and interaction in the team;
(f) external and internal factors that influence your team's work and progress.

2) to provide consent and two-three opportunities for my observation of how your research team is working on its project. No formal interviews will be taken during the visits. If I come across issues that require clarification, I may follow up with some informal questions and take notes then.

Risks and Benefits of Participation:

By participating in the study, you may be asked to answer questions about your team project that make you feel uncomfortable, or that you may feel puts you at risk of revealing confidential ("know-how") or sensitive information. All reasonable precautions will be taken to ensure no one other than the researcher sees your responses (see Confidentiality and Anonymity section below). You may also choose not to answer a question at any time throughout the interview process.

The benefits to participating in this study include the satisfaction that you are contributing to the scientific pursuit of knowledge and a deeper understanding of the factors facilitating and hampering the work and progress of TD research teams.

Confidentiality and Anonymity:

The records of this study will be kept private. In any sort of report that will be published as a result of the study, I will not include any information that will make it possible to identify a subject. Research records will be stored securely and only the researcher will have access to the records. In particular, all original digital audio recordings will be kept on a private computer and also on a back-up device. Any identifying information such as names in the transcriptions of the audio recordings will be replaced by identifies, such as Group1: group leader 1, researcher 1.1, researcher 1.2; Group 2: group leader 2; researcher 2.1, researcher 2.2 etc.), in compliance with the University of Minnesota's Safe Computing Recommendations. All original digital audio recordings will be erased after two years from the time of interview.

Voluntary Nature of the Study:

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

Contacts and Questions:

The researcher conducting this study is: Oleksandr Tkachenko, PhD Candidate in Organization Leadership, Policy, and Development. You may ask me any questions you have any at this stage. If you have questions later, you are encouraged to contact me at: Burton Hall, 178 Pillsbury Dr. SE #206, OLPD, University of Minnesota. My mobile is: 612-xxx-xxx, e-mail: tkac0022@umn.edu. My adviser's contact information is the following: Dr. Alexandre Ardichvili; 612-xxx-xxxx; ardic001@umn.edu.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

You will be given a copy of this information to keep for your records.

Statement of Consent:

I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

Signature: _____

Date: _____

Signature of Investigator: _____

Date: _____

Appendix H.

Interview Questions

1. Could you please tell me about your research project?
    a) What is the objective of this project? What different kinds of expertise are central to the success of this project? Which group members contribute what expertise?
    b) How did the team members come together? How did you learn about your joint interests? How long have you worked together?

2. Where is your team regarding reaching its objective?
    a) What has your team accomplished so far?
    b) What is it that your team is working on these days?
    c) What are your next steps?

3. Could you tell me about the cross-disciplinary integration in your project?
    a) What are the disciplines?
    b) What is unique about this integration?

4. What factors are influencing the work (and progress) of your team?
    a) Could you tell me more about *X, Y, Z*? How is it influencing your team's work?
    b) How is your team responding to *X, Y, Z*?
    c) What about your past experiences? What factors influenced the work of your team in the past?

5. Could you describe how things get done in your team?
    a) What is exactly that *you* do in this research? What is your role?
    b) What do other team members do? What are their roles?
    c) Did you notice any changes in how things get done now as compared to the time when you started working on this project? If evident: What did change? Why did it change?

6. Could you describe how you interact with each other?
    a) How do you communicate with each other when you're working on the project? When you do not work on the project?
    b) Did you observe any changes in your interaction since you started working on the project? If evident: What did change? Why did it change?

7. How could this institution (the University, your college, your department) assist your team in undertaking your project?
    a) How could it have assisted you in the past?
    b) In the nearest future?

8. Is there anything we haven't talked about yet today that you'd like to mention?